

New Scientist

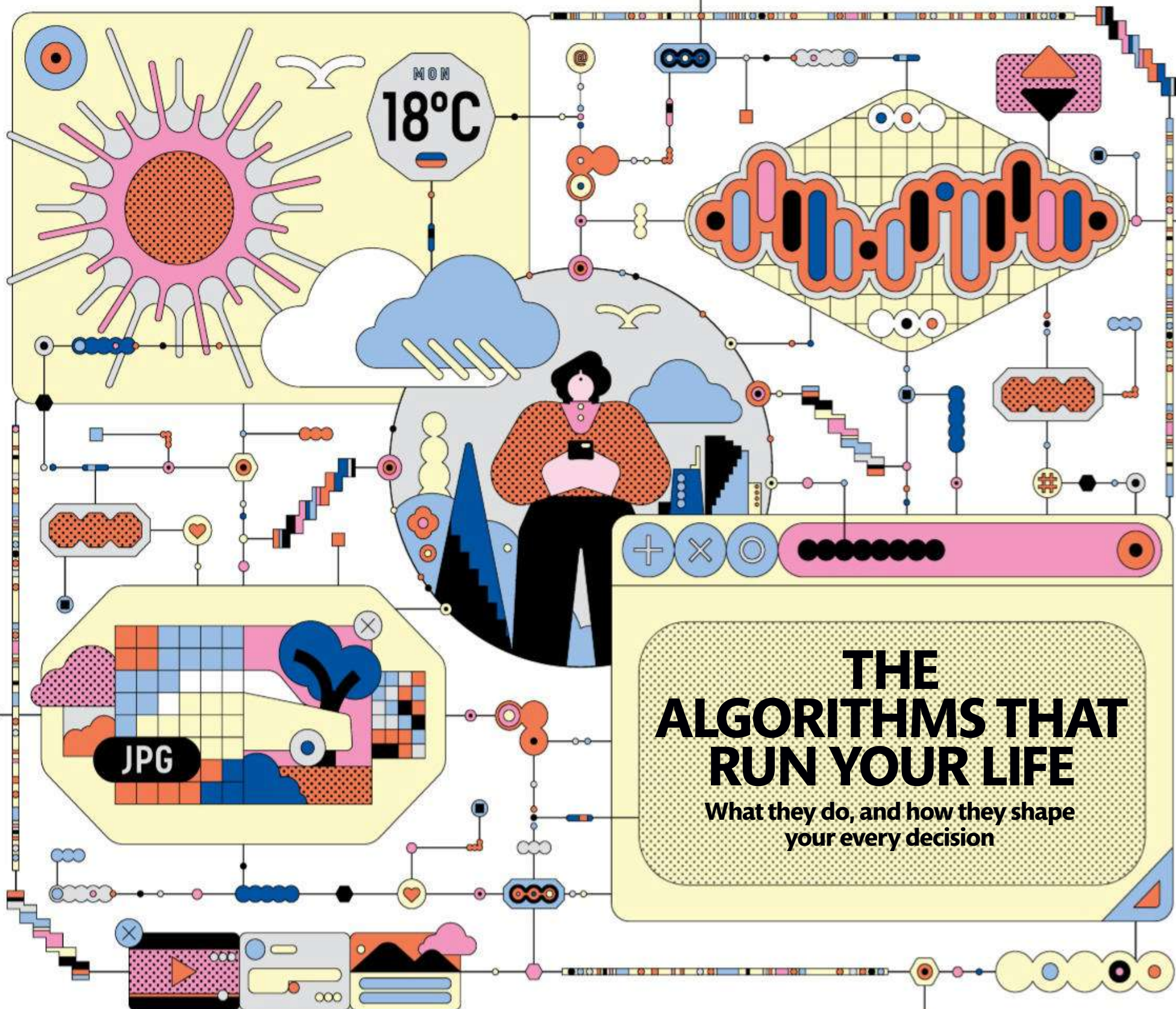
WEEKLY 19 June 2021

SECRETS OF
ANCIENT GLACIERS

CAN YOU CATCH
COVID-19 TWICE?

MYSTERY SPACE
SIGNAL EXPLOSION

YOUR DOG MAY NOT
LIKE YOU AS MUCH AS
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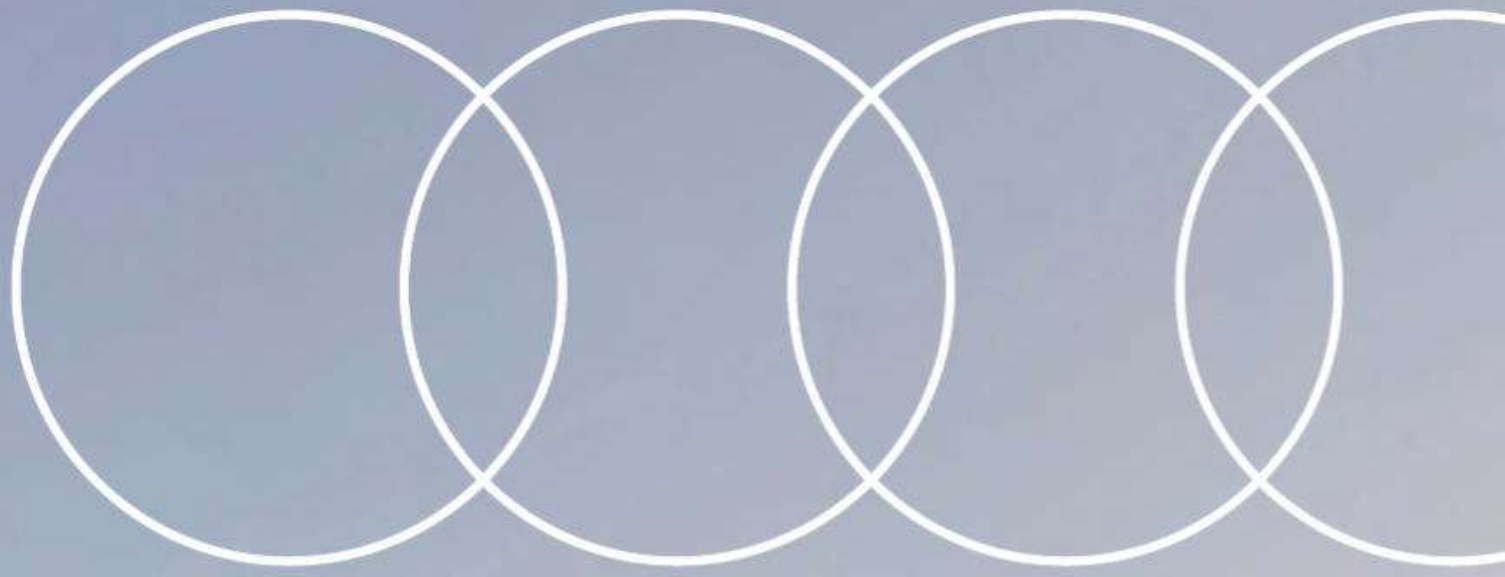
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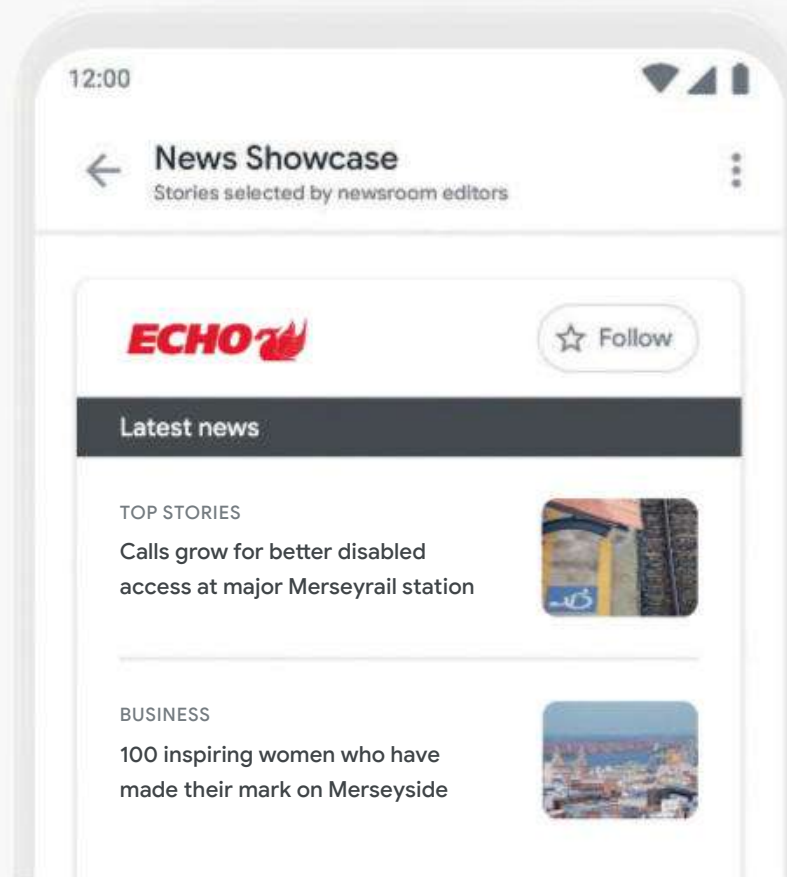
The Audi e-tron GT is a battery electric vehicle requiring mains electricity for charging. Figures shown are for comparability purposes and may not reflect real life driving results.



Zero emissions while driving. Model shown is Audi RS e-tron GT. Features optional equipment.



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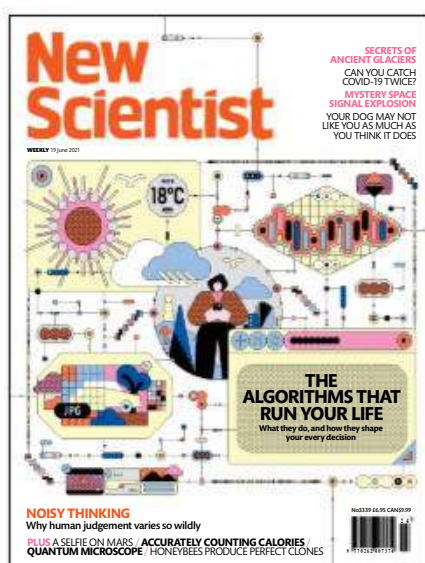
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The future of healthcare

The coronavirus pandemic has thrown the spotlight on human health and the role of science like never before. Find out what the future of healthcare will look like in this special one-day event. You will hear inspiring talks from a selection of scientists at the forefront of research and experts on healthy living. Many sessions will also feature audience questions, giving you the opportunity to be part of the conversation. Join us on 26 June. Tickets available now.

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Podcast

Weekly

For the first time in 18 years, a new drug has been approved to treat Alzheimer's disease. The team discuss this huge news and why there are still reasons to be cautious. Also on the pod: Google researchers have mapped the neurons in a part of the brain, and a team has revived an animal frozen in permafrost for 24,000 years.

newscientist.com/podcasts

Online

Covid-19 daily briefing

All the latest developments in the covid-19 pandemic in one briefing. Plus links to exclusive news, features and interviews. Updated daily at 6pm BST.

newscientist.com/coronavirus-latest

Video



Look up A dose of awe can do you a lot of good, explains Sam Wong

Newsletter



MICHAEL LINGBERG/ALAMY

Talking about death When pets die, explain it to children honestly

Newsletter

Parental Guidance

A newsletter about evidence-based parenting. In the latest edition, Catherine de Lange looks at how to talk to children about death. It turns out to be an uplifting subject: do it honestly and it can leave children feeling reassured.

newscientist.com/sign-up/parental-guidance

Video

Science with Sam

Being awestruck can bring a host of benefits, from lowering stress to boosting creativity. But what is awe, and how do we get more of it in our lives? Sam Wong explains it all in our latest video. Subscribe to our channel for more mind-blowing ideas and explainers.

youtube.com/newscientist



Since *New Scientist's* inception, we have been for "all those interested in scientific discovery and its social consequences". However, science journalism has a diversity issue, meaning many of those interested people are under-represented in the profession. For the past two years, we have been running an internship scheme to help address this, and I am delighted to announce that we are continuing it this year.

The six-month internship is open to anyone from an ethnic minority background. It will be jam-packed with on-the-job training in news and features writing, as well as subediting. It pays the 2021 London Living Wage and will be based on the London news desk – though we can't yet say whether interns will be working from the office or home.

We have trained six brilliant science journalists through the programme to date. Their names regularly appear next to articles in this magazine, as well as in other publications.

If you think you are right for this opportunity, then we would love to hear from you. No CVs required, just a degree in a science or technology-related field and a demonstrable interest in writing or journalism. The closing date for applications is 30 June 2021.

For full details, please visit:
tinyurl.com/nsinternship2021

Timothy Revell

Comment and culture editor

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Get with the program

For a healthier relationship with algorithms, we must learn how they actually work

IT IS hard to go a single day without hearing about the two huge crises that humanity is grappling with right now, the covid-19 pandemic and the climate emergency. In both cases, science and technology have been crucial in identifying the problems and their possible solutions.

Those two issues might seem like quite enough to be going on with, but we shouldn't take our eyes off another troublesome area in which the role of science is vital: the rise of algorithms.

We might hear less about them, but algorithms are just as hard to avoid as talk of the pandemic. Constantly operating in the background of our digital lives, they do a huge variety of jobs, suggesting what we should read, watch and buy online.

They are also increasingly used to help us make tricky decisions offline. The trouble with this is that the workings of algorithms, especially those based on artificial intelligence, are often impossible to fully understand. We outsource all kinds of decisions to computers, yet can't easily see how these were made.

"We outsource all kinds of decisions to computers, yet can't easily see how these were made"

One instance came last year, when Ofqual, the regulator of exams in England, had tough decisions to make about assigning grades to pupils who had their exams cancelled due to the pandemic. It decided to ask teachers for their assessments of pupils' performances and

then moderate these using an algorithm.

The hope was to avoid wild grade inflation. The result, however, was that many students ended up with drastically worse results than they had expected, with – initially, at least – little explanation.

Maybe it is time to admit that we need a healthier relationship with algorithms, one where we understand the basics of how they work. A good first step would be to get to know a few of the algorithms that really matter in our daily lives, which is why we decided to do just that, starting on page 34.

The trouble that algorithms cause is nowhere near the scale wrought by the pandemic and global warming. But who knows where we will end up if we carry on delegating decisions to machines we can't completely understand? ■

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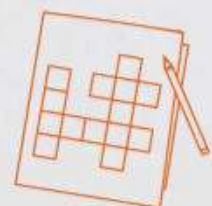
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Prof. Anne-Marie Minihane
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Deep sea evolution

Fish come in all shapes and sizes in the deep **p12**

Smell of fear

Dogs seem able to sniff out the whiff of terror **p13**

Double infection

How likely are you to catch covid-19 twice? **p14**

Dark matter rules

Evidence for mysterious particles mounts up **p16**

Chips, chips, chips

Google AI designs processors that could run future AIs **p18**



WPA POOL/GETTY IMAGES

Boris Johnson confirms a four-week delay to the 21 June easing of lockdown

risk of hospitalisation compared with the alpha variant. However, it isn't yet known what effect the delta variant is having on deaths. "We just don't have enough information on that yet," says Chris Robertson at the University of Strathclyde, UK, part of the Public Health Scotland team that analysed data from 99 per cent of the country's population of 5.4 million. About 1.9 million of them are unvaccinated.

It also isn't yet clear what effect the delta variant is having on demand for intensive care beds, according to Rowland Kao at the University of Edinburgh, UK, who wasn't involved in the research.

Full lifting of England's restrictions would have allowed unlimited guests in people's homes, no capacity restrictions in pubs, cinemas or theatres, open nightclubs, full sports stadiums and no limit on guest numbers at weddings and funerals. Timetables for lifting restrictions vary in the rest of the UK.

Public Health Scotland team leader Aziz Sheikh, also at the University of Edinburgh, welcomed the decision to postpone. "It will give the opportunity to increase the proportion of the population who can get two doses," he says.

A delay will also give scientists more time to assess the true dangers of the delta variant, says Mark Woolhouse, also at the University of Edinburgh.

In December, the UK decided to extend the interval between vaccine doses from the manufacturers' recommended three to four weeks to up to 12 weeks, in order to provide partial protection to the maximum number of people. Anyone over 40 will now be eligible to get a second jab eight weeks after the first. ■

Coronavirus

England lockdown extended

End of lockdown postponed in England amid findings that the delta variant doubles the risk of hospitalisations, reports **Graham Lawton**

THE lifting of the final covid-19 restrictions in England, scheduled for 21 June, has been delayed by our weeks to head off the risk of a new wave of covid-19 caused by the delta variant. The move will buy time to vaccinate more people.

According to the UK government's Scientific Advisory Group for Emergencies, or SAGE, computer models of lifting restrictions project a "large resurgence" in cases and hospital admissions, which could be "considerably" larger than previous waves.

After falling for months, the number of new cases of covid-19 is rising again in all four nations of the UK. Scotland is worst affected,

with England second. The rise is fuelled by the delta variant, which is believed to be about 60 per cent more transmissible than the previously dominant alpha variant and is now the cause of almost 90 per cent of new cases in the UK.

The good news, according to Jim McMenamin, Public Health Scotland's national covid-19 incident director, is that vaccines are still very effective.

Figures from Public Health England show that double vaccination is 80.8 per cent effective against symptomatic

disease caused by the delta variant, but single vaccination is much less effective, providing just 33.2 per cent protection. Equivalent figures for the alpha variant are 88.4 per cent and 50.2 per cent. "We need to get these second doses out there," says McMenamin. The data set doesn't distinguish between the different vaccines. About a third of people in England are still totally unvaccinated.

Other findings from Scotland suggest that, for unvaccinated people, the delta variant approximately doubles the



Daily coronavirus news round-up

Online every weekday at 6pm BST
[newscientist.com/coronavirus-latest](https://www.newscientist.com/coronavirus-latest)

Coronavirus

It isn't too late to eliminate

Countries opting to eliminate covid-19 rather than reduce its spread have fared best – and there's still time to adopt the strategy, reports **Graham Lawton**

COUNTRIES that pursued strict pandemic suppression strategies fared better on measures of health, wealth and civil liberties than those that didn't, according to an analysis published this week (*The Lancet*, doi.org/f89p). The analysis covers the pandemic's first year from February 2020, but has relevance to ongoing efforts to end it. Moving to an elimination strategy even at this stage could lead to better health, prosperity and freedom, say the authors.

The researchers compared 37 wealthy nations' deaths from covid-19, GDP growth and strictness of lockdown measures. They classified the countries into two groups: five "elimination" countries, which took maximum action at all times to suppress the outbreak; and 32 "mitigation" countries, which reacted to events to stop their health systems from being overwhelmed.

"What we found was that there were far fewer deaths in the five elimination countries compared to others," says team member Jeffrey Lazarus at the Barcelona

"An elimination strategy is best for the economy, best for health and impinges the least on civil liberties"

Institute for Global Health in Spain. "Likewise, swift lockdown measures in line with elimination were less strict and of shorter duration, and we found that elimination is superior to mitigation for GDP growth."

An elimination strategy essentially means mass testing, supporting people infected with the coronavirus to isolate, tracing those they have come into contact with and helping them to self-isolate too, border surveillance, and swift and stringent lockdowns when needed. This is "infectious



JUNG YEON-JE/AP VIA GETTY IMAGES

South Korean soldiers disinfect streets in the Eunpyeong district, Seoul

their success. "It is easier to protect the borders of an island state, if you want to," he says. But it isn't impossible for other countries to police their borders. Denmark nearly qualified as an elimination country, says Lazarus, but struggled to control Danes living in Sweden from going back and forth over the Øresund Bridge.

The analysis can inform policies for the rest of the pandemic, says Lazarus. "Obviously it's a retrospective study, but we can learn from the past." He says that the crisis isn't over and with more transmissible variants on the loose, countries that act as if it is over before they have high-enough levels of vaccination will find themselves repeating mistakes of the past.

It is never too late to pivot to an elimination strategy and doing so now could mean a much healthier, wealthier and freer summer in the northern hemisphere, he says.

Overcoming economic and libertarian prejudices against elimination won't be easy, says team member Ilona Kickbusch at the Global Health Centre in Geneva, Switzerland. She was part of a group of scientists in Germany that unsuccessfully lobbied for an elimination strategy. They were branded as "Stalinists trying to close down society", she says. "Actually our argument was just the opposite."

The analysis has been criticised for using 20/20 hindsight in its selection of countries, says Martin McKee at the London School of Hygiene & Tropical Medicine, who wasn't involved in the study. But its conclusion that the elimination strategy produces the best outcome stands up, he says. ■

disease class 101", says Lazarus.

According to Lazarus, these measures are often criticised on the grounds that, while they may protect health, they damage economies and infringe on civil liberties. In fact, the study shows they are superior on all of these measures.

The five elimination countries are Australia, Iceland, Japan, New Zealand and South Korea. They didn't succeed in eliminating the virus but set out to do so and stuck to their guns, says Lazarus.

The 32 mitigation countries are the other members of the Organisation for Economic Co-operation and Development, minus Costa Rica. The researchers wanted to include China but couldn't get enough data.

Elimination countries had just 4 per cent of the per capita death toll of mitigation countries. Their GDP growth returned to pre-pandemic

levels early in 2021, while the 32 are still below pre-pandemic levels. Crucially, elimination had less of an impact than mitigation on civil liberties, according to a "lockdown stringency" index developed by the University of Oxford.

Alice Roberts at the University of Birmingham, UK, a member of the UK's Independent SAGE group, describes the analysis as a "very firm evidence base that an elimination strategy is best for the economy, best for health and impinges the least on civil liberties, which seems to be the main argument against it".

Island benefits

It is notable that the five elimination countries are island nations or South Korea, which has one tightly controlled land border. Lazarus accepts that isolation could have something to do with

Chemistry

A robotic chemist could reveal the recipe for Earth's primordial soup

Katharine Sanderson

RECREATING the compounds and experimental conditions that interacted over billions of years to create life on Earth is impossible in the lab. But an autonomous robot that can shorten the time it takes to test possible mixtures could help reveal the precise combination that let proteins, DNA and enzymes emerge from the prebiotic soup on early Earth.

Lee Cronin at the University of Glasgow, UK, and his colleagues built a robotic chemist that can mix simple molecules together, watch them react, analyse the results and decide what else to add. Over several weeks, this robot can start to recreate a prebiotic soup with almost no input from human chemists, he says.

"We wanted to remove the bias from the experiments and cover as much chemical space as possible to look for the spark of life," says Cronin.

The set-up includes a tangle

of tubes connecting 18 flasks of different starting materials to a central reaction vessel containing a range of clean, dry minerals such as quartz, ulexite and pyrite.

The starting materials are all small molecules with no biological or catalytic function, including simple acids, organics, reducing agents and some inorganic molecules like copper sulphate.

The robot chooses two or three of these reagents to suck into the reaction vessel, where the mixture is stirred and heated for an hour, then allowed to settle. It analyses the sample, and a portion is taken away for storage and human analysis later. A small amount is left as a seed mixture, before the robot adds a fresh batch of reagents and the process repeats. The team ran the robot for up to 150 of these cycles over many days (*Nature Communications*, doi.org/gkhvsg).

The decision on whether to let

a reaction continue or whether to introduce a new molecule into the brew is based on a mass spectrometer, which reveals the size of the molecules in the mixture. If these readings suggest no change has happened, the robot will work to push the system

18

Number of materials a robot mixes to investigate the origins of life

away from a state of equilibrium by adding something new in the next cycle. "It's an anti-boredom algorithm," says Cronin.

The robotic chemist doesn't allow us to work out how life formed yet, but it is a useful tool to let us step towards it – and a vast improvement on the effort one person at the bench could make, says Sijbren Otto at the University of Groningen in the Netherlands.

With the right mix of starting

materials, we could learn a great deal, says Otto. "The hope with these experiments is that something autocatalytic emerges from it," he says, meaning when a reaction produces its own catalyst. These reactions are considered essential for life to emerge.

Judit Šponer at the Czech Academy of Sciences says that humans tend to get in the way in origin-of-life experiments, so this robot significantly reduces such bias.

"We've seen tentative evidence of molecular replication," says Cronin. Complex molecules are forming, and despite being diluted away at the start of each new cycle, those molecules persist, he says.

He is planning a bigger version of the robot. "This is a dummy run," he says. With more complex algorithms, the researchers hope to see evidence of large, complicated molecules that can process information. ■

Animal behaviour

Female seahorses cheat on partners they can't smell

MONOGAMOUS female seahorses cheat on their male partners when they can't smell them any more.

"Seahorses can express incredible loyalty and affection once a pair has bonded during the reproductive season," says Dong Zhang at the Chinese Academy of Fishery Sciences in Shanghai.

The curvy-tailed couples usually stay together for months or years. They live within a few metres of each other and meet at dawn for "morning greetings" that reinforce their bond – swimming in parallel, brightening their hues and "dancing", says Zhang.

They reproduce through male pregnancy after the female deposits her eggs into the male's abdominal brood pouch. The couple takes a mating break during the 12 to 20 days the male is pregnant, but then they mate again within 48 hours after he gives birth.

Zhang and his team wondered what kept each female faithful during the waiting time and how she distinguished her mate from other males. They tested 200 pairs of virgin, lab-raised lined seahorses (*Hippocampus erectus*) in various situations. They allowed them to couple up, placing a female and her pregnant mate in a tank with a second male that had just given birth, which may have made him more attractive because he had proven to be fertile, says Zhang.



MICHAEL PATRICK O'NEILL/ALAMY

Then they placed the pregnant mate either in a mesh cage, an opaque, open-ended pipe or a transparent plastic bag. These barriers respectively blocked morning greetings, vision or odours.

Lined seahorses are monogamous and bond with "morning greetings"

After the mate gave birth, the researchers let all three seahorses swim freely. If a female hadn't been able to see or greet her mate during pregnancy, she still chose him over the other male, except for a few rare cases in which a female didn't choose either male, says Zhang.

However, 75 per cent of the females that hadn't been able to smell their enclosed mates chose the other male (*Behavioural Processes*, doi.org/ghmq). It is possible that while the mate was in the transparent bag, the female forgot his scent and got used to the other male's odours, says Zhang. ■

Christa Lesté-Lasserre

Biodiversity

Why fish in the deep sea take so many strange forms

Jake Buehler

WITH eels that have heads shaped like tweezers and anglerfish that look like light bulbs, the deep sea is a hotspot of body-shape evolution.

Previous research has shown that fish metabolism and swimming strength decrease with ocean depth, says Christopher Martinez at the University of California, Davis. But there has been no comprehensive comparison of the shapes that fish bodies take at different depths.

He and his colleagues were part of a project to measure the physical proportions of about 6000 fish species at the Smithsonian National Museum of Natural History in Washington DC.

Using this vast new database, they compared the body shapes of more than 3000 fish species from habitats ranging from surface waters to the abyss. They found that fish in the deep sea are nearly twice as diverse as shallow water fish in terms of body shape (*Ecology Letters*, doi.org/gkbjb8).

There are a lot more species in the shallows, but many are fish with spindle-like shapes, such as tuna, or more compressed shapes, such as butterfly fish.

Martinez suggests this is because the turbulent, light-rich region closer to the surface is full of active prey and predators, which creates an evolutionary pressure to develop a strong, manoeuvrable body. This funnels shallow-water fish into a handful of streamlined shapes.

In the slow, quiet deep, athleticism isn't as important for survival, he says. Released from some of the constraints of natural selection, surreal proportions emerge.

Emily Kane at the University of Louisiana at Lafayette says the findings "serve as a good reminder that [traits] are not always necessarily evolving to some sort of selective pressure. It can be a release from those pressures, as well, that causes diversification."

Animals

You may think your dog likes you more than it does

Christa Lesté-Lasserre

DOG owners tend to overestimate the bond they have with their pet, which could have implications for preventing dogs from roaming far from home or attacking animals.

"As caregivers, we need to develop better bonds with our dogs, not only for our own well-being and the dog's well-being, but also for nature," says Lorena Saavedra-Aracena at the University of Magallanes, Chile.

Previous research has shown that unsterilised male dogs and undernourished dogs tend to roam longer distances, but this isn't always the case. Saavedra-Aracena wondered if the dogs' attachment to their caregivers also played a role, so she and her colleagues equipped 41 free-roaming pet dogs with GPS collars, tracking their journeys on Navarino Island in southern Chile for about 3 weeks.

Although most of the dogs stayed within a 300-metre radius of home, some travelled up to 28 kilometres away. One even swam in a near-freezing canal for an hour chasing native water birds, says Saavedra-

Aracena. The dogs regularly brought home carcasses of native birds and muskrats, and 80 per cent of them harassed other animals, mainly local cattle and sheep.

The researchers asked owners to complete a standard survey about the dog-human bond. Then, to get the "dog's point of view", they ran a behaviour test adapted from evaluations of children's bonds with their

28km

Furthest distance from home that a dog was tracked

parents. Each dog was reunited with its owner in a new place, addressed by strangers, left alone in an unfamiliar room and given free access to a second, empty room.

The team found that lower scores on the bonding test correlated with greater roaming distances. The owners of these dogs had assessed their pets' attachment to them as much stronger than the bonding test suggests, says Saavedra-Aracena (*Applied Animal Behaviour Science*, doi.org/ghzv).

It is possible that people place too much weight on their dog's

enthusiastic greetings as a sign of bonding, she says. Dogs that roamed the most often showed the most exuberant responses to seeing their owners again. They may have simply become accustomed to carrying out an "evolutionary" ritual of bond re-establishment that is typical among pack members after long absences, says Saavedra-Aracena.

Relationships with other humans may have weakened the dog-owner bond in far-roaming dogs, she says. Neighbours sometimes give them food, and tourists hiking on the island offer walks and companionship, potentially reinforcing the roaming problem.

Outside opportunities for food, exercise and socialisation could all affect bonding, says Paul McGreevy at the University of New England in Australia. These aspects are critical to dog welfare and represent needs that must be met by its caregiver, both for building attachment and for curbing roaming behaviour. "If any one of those three pillar resources is lacking, then the dog can be justified in going elsewhere," he says.

Although it has become less common to see roaming dogs in industrialised nations, they continue to roam freely in most societies, says Saavedra-Aracena. Even when owners restrain their pets, some dogs can escape their leashes or enclosures.

"Unlike children who loosen bonds with their parents as they grow older, dogs can become more attached to their caregivers throughout their lives," she says. "So it's never too late to work on building that bond, playing with your dog and just spending time with him, getting to know him better, just like you would with a human partner."

Your best friend may not feel quite the same about you



SHUTTERSTOCK/DAZ STOCK



Space exploration

Selfie from Mars

The Zhurong rover took a picture with its landing platform

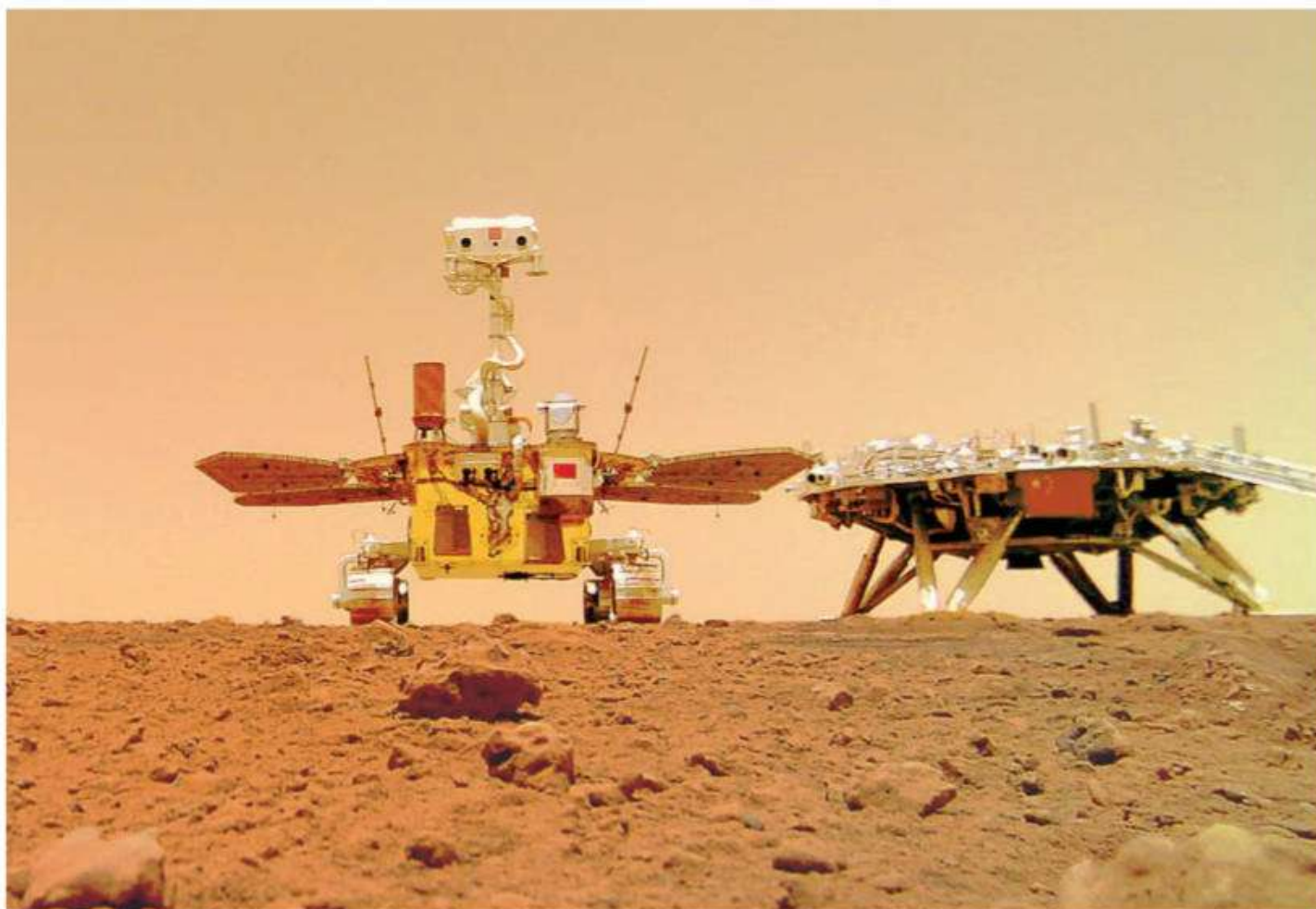
Andrew Jones

CHINA has released the first batch of science images from its Zhurong Mars rover, following its successful landing on 14 May.

In one picture, right, Zhurong carefully orchestrated a group selfie with its landing platform. To do this, the rover travelled 10 metres south, released a small wireless camera, then headed back towards the lander to pose for the shot.

The update confirms that Zhurong has been active, despite a lack of information from the China National Space Administration since the rover crawled on to the surface on 22 May.

Teams in China will now use the images to make a travel plan. Among the rover's science instruments are panoramic and multispectral cameras for imaging and analysing its surroundings and a ground-penetrating radar which will peer below the surface for evidence of water and ice. ■



CNSA

Pheromones

Seizure alert dogs may detect the smell of fear

DOGS that can predict when their owners are going to have an epileptic seizure may be recognising the “smell of fear”.

A small study suggests that a compound in sweat recognised by seizure alert dogs may be the same as one released when people watch scary movies.

Some animals communicate by releasing hormones that can be smelled, called pheromones, but it is unclear if human pheromones exist. Some small studies have hinted that we may change our behaviours based on the scent of others – dental students perform significantly worse when treating mannequins wearing T-shirts from people who were stressed

compared with those from people who were calm, for instance.

Edward Maa, at Denver Health Medical Center in Colorado, came across the idea of fear pheromones because of his work with a charity that trains dogs for people with epilepsy, called Canine Assistants.

The dogs are trained to press a button on a phone if their owner has a seizure. Many also learn to recognise if their owner is going to have a seizure up to an hour in advance. It is thought that dogs predict a seizure by smelling a change in the person's sweat, triggered by brain changes that eventually develop into a seizure.

In the new study, Maa and his colleagues used four assistance

dogs that had been taught to touch the trainer's left hand if they smell a scent indicating an imminent seizure, and their right hand if that scent is absent.

The animals were given 90 pads to sniff containing a variety of sweat samples. These included

“The dogs indicated they could smell a seizure scent in 69 per cent of the fear sweat samples”

sweat taken while people watched the film *It*, exercise sweat and samples taken from someone during a seizure and when seizures were absent.

The dogs indicated they could

smell a seizure scent in 96 per cent of the seizure samples and 69 per cent of the fear samples. They correctly rejected all the other samples (*Epilepsy & Behavior*, doi.org/ghz5).

Previous research has narrowed down the field of potential pheromone candidates to three chemicals, with one called menthone thought to be particularly crucial to dogs' ability to identify a potential seizure.

Before menthone can be considered a pheromone, however, it needs to be shown that it can change people's behaviour, says Jasper de Groot at Radboud University in the Netherlands. ■

Clare Wilson

Coronavirus

Covid-19 reinfection is rare

If you are unlucky enough to catch covid-19 twice, the second bout is likely to be mild

Graham Lawton

BACK in August 2020, a worrying report came in from Reno, Nevada. A 25-year-old man who had recovered from covid-19 in April had fallen ill with it again, and this time his symptoms were worse. He had tested negative for the virus in between bouts, so had been infected twice.

Other reports of reinfection were also circulating at the time, raising fears that infections don't lead to long-lasting immunity.

Nine months on, however, those fears have receded. Not only is vaccination proving highly effective, a number of large studies in Europe and the US have now shown that while reinfection is possible, it is rare and usually produces mild disease at worst.

One such study was carried out over four months in 100 care homes for older people in England. Between June and November 2020, Maria Krutikov at University College London and her colleagues took blood samples from 682 residents and 1429 staff and tested them for antibodies against SARS-CoV-2. Over the next four months, all the subjects were regularly screened for infection using PCR tests.

Initial blood tests found that



ADRIAN DENNIS/APP VIA GETTY IMAGES

634 of the total 2111 people were antibody positive, meaning they had already been infected. Only 14 of them subsequently had a positive PCR test – a reinfection rate of just over 2 per cent.

In comparison, 204 of the 1477 (14 per cent) people whose blood test came back antibody negative

subsequently caught the virus. Data from residents and staff who had been vaccinated more than 12 days before their samples were taken were excluded from the analysis (*The Lancet Healthy Longevity*, doi.org/gkc8dr).

Eleven of the 12 reinfected people for whom symptoms were recorded had symptoms such as a cough or fever, but none required hospitalisation. The researchers warn that the numbers are quite small, so it is hard to draw firm conclusions, but it seems that previous infection reduces the risk of reinfection by about 70 per cent. This is in line with another study of healthcare workers in England, also carried out between June and November 2020.

Research carried out in Denmark during the second wave of infections there found an even higher level of protection among people previously infected in the first wave, around 80 per cent.

A woman tests herself for covid-19 at Uxbridge Civic Centre in London

Meanwhile, a non peer-reviewed study of 50,000 healthcare employees in Ohio between December 2020 and April 2021 found a reinfection rate of zero.

“The concern for covid-19 is that we might not see complete protection or that protection might fall with time,” says Alexander Edwards at the University of Reading, UK. “It’s therefore great news to see that reinfection wasn’t seen very often. However, it’s important to also confirm that reinfection does occur, so protection is not complete. We expect that natural infection should protect against severe infection, but we still don’t have enough data to know this.”

We don’t know to what extent new variants change the picture. The care home study in England was done when the alpha variant was becoming dominant in the UK. “The low number of reinfections suggest a good level of immunity against this variant following natural infection,” says Krutikov. However, it predates the rise of the delta variant, which now causes

How long does immunity last?

After a natural covid-19 infection, the number of neutralising antibodies, our first line defence, declines over four months. B-cells, however – which form an immune memory that ensures protection for decades – are present 11 months after infection and were stable in a small number of people tested at 15 months (*Nature*, doi.org/gj6hmb).

Vaccine responses are likely to be similar. Most studies suggest

that vaccines provide good protection against covid-19 for at least six months. Trials into whether they work for longer are still ongoing.

We don’t yet know what level of immune cells equates to immunity, but models suggest that while immunity to infection might fade, immunity against severe disease could last years. The impact of variants on immunity duration isn’t yet clear.

“The low number of reinfections suggest a good level of protective immunity against alpha”

91 per cent of cases in the UK.

“The study does not inform directly the protection against reinfection with this variant,” says Rowland Kao at the University of Edinburgh, UK.

Further information on reinfection is unlikely to be forthcoming because mass vaccination makes it difficult to study enough unvaccinated people, says Edwards. ■

Military technology

Interceptor takes out drones with Silly String-like strands

David Hambling

THE US has developed a drone interceptor that fires something resembling Silly String into their rotors, bringing them down with minimal risk of accidental damage.

The interceptor was created by the US Defense Advanced Research Projects Agency (DARPA). It is launched from a vehicle and guided by radar that can automatically identify and track small drones.

Once the interceptor has a target drone in sight, it releases string-like streamers – their exact composition is unknown – to disable it. The system can also launch multiple interceptors to deal with several incoming drones simultaneously, and the interceptors are reusable.

DARPA says it wants to provide drone defences for convoys and other mobile units in heavily populated areas, where normal military weapons would create too much risk of civilian casualties. Existing interceptor drones, like the Coyote already used by the US military, carry an explosive warhead, while other projects rely on nets or ramming, which require more precise aiming.

"The issue of a hostile drone – potentially with explosives attached to it – falling to the ground and possibly injuring civilians exists," says Robert Bunker, security analyst with C/O Futures. "But it's a far better option than targeting such a drone with indiscriminate machine gun fire."

Because it doesn't require explosives, this type of interceptor might also be suitable for civilian use, such as defending airports, sports stadiums and other vulnerable sites. But Bunker notes that, if interceptors become common, counter-countermeasures will evolve. "We could see a type of escalation where hostile fighter drones protect the bomber ones from the counter-drones, as we see with manned aircraft," he says. ■

Animals

Fox breeding suggests that domestication boosts brains

Christa Lesté-Lasserre

OUR understanding of how domestication changes the neurobiology of a species may be wrong, results from a 60-year experiment to breed tame foxes suggest.

Usually, domesticated animals have smaller brains than their wild counterparts, but animals raised in a Russian fox farm experiment in Novosibirsk haven't followed that trend. On the contrary, fox lines purposefully bred for either a good or a bad relationship with humans had larger brains than those that weren't, says Erin Hecht at Harvard University, who is part of a team studying specimens from the experiment.

The unexpected findings "suggest revision of existing thinking about domestication" is needed, perhaps towards an idea that brains respond to behaviour-related pressure, at least initially, by developing more grey matter, says Hecht.

Starting in 1959, project scientists began selectively breeding silver foxes (*Vulpes*

Silver foxes (*Vulpes vulpes*) are being selectively bred

vulpes) in a fur farm. With each generation, they chose the tamest animals to reproduce together, while also picking the most aggressive animals to breed together. A third group of foxes was left to mate without selection for behavioural aspects, as a control.

The idea, researchers said at the time, was to create a model of the animal domestication process. The project has led to dozens of published papers, but has also seen criticism

1959

Year the Russian fox farm experiment began

for developing captive animals that are fearful of humans.

Now, an international team of researchers has examined the brains of 30 males from recent generations of those foxes. The group took the preserved left hemispheres of the brains of 18-month-old foxes and examined them under high-resolution magnetic resonance imaging (MRI).

Surprisingly, the control foxes – the third group – had the smallest brains, says Hecht.

Equally surprising, the "tame" fox brains were, on average, nearly identical in size and structure to the "aggressive" fox brains. In particular, the tame and aggressive foxes had similar changes in the same parts of the brain that are apparently associated with tameness in dogs compared with wolves, including the prefrontal cortex, hippocampus and amygdala (*The Journal of Neuroscience*, doi.org/ghz6).

The study provides an unprecedented look into individual brain structures, says Ana Balcarcel at the University of Zurich in Switzerland. "They're literally going deeper into the brain, and that's such a novel thing," she says. "It's raising more questions than answers at this point, but that's very exciting."

For Martine Hausberger at the University of Rennes in France, however, the conclusions are less compelling. The fox farm experiment can't be considered a reliable model for studying domestication, in part because its "wild" animals are captive, rather than hunting and fending for themselves, she says.

Furthermore, the foxes' brains may have been shaped according to how they were treated, with the tame ones certainly having more enriching interactions with handlers and the aggressive ones possibly being more mentally stimulated when handlers approached their cages. "Brain sizes evolve in each individual according to personal experience," says Hausberger. "So are these brain differences genetic, and related to behaviour alone? I'm not convinced. It seems like a bit of a shortcut to say that they are." ■



ALL CANADA PHOTOS/LAMY

Cosmology

Dark matter rival fails key galaxy merger test...

Bas den Hond

GALAXIES in the early universe were merging up to 10 times more than is predicted by theories that tweak the laws of gravity, known as modified Newtonian dynamics or MOND. This rate of mergers is instead in line with theories that take into account dark matter, the invisible, currently undetected stuff thought to make up about 85 per cent of all matter.

Christopher Conselice at the University of Manchester, UK, and his colleagues analysed observations of half a million galaxies, from the local universe out to 18.6 billion light years away. When you look at the deep universe, you see light from the past, so the distant galaxies formed when the universe was more compact.

As such, further-away galaxies met and merged more frequently than they do in the local universe today, said Conselice, who presented the

85%

Dark matter is thought to make up this share of all matter

work at a virtual meeting of the American Astronomical Society on 9 June. The team counted galaxies in the early universe that looked like they were about to merge, as well as irregular galaxies that were clearly the product of a recent merger.

Conselice estimates that the merger rate in the early universe was five to 10 times higher than would be predicted by MOND theories that tweak the laws of gravity instead of assuming the presence of dark matter.

Both ideas were put forward to explain why galaxies rotate faster than would be expected based on the mass of their stars



NASA/JPL-CALTECH/ISTCI/VASSAR

and gas. “But one of the things that really hasn’t been considered very much is how dark matter would affect galaxy evolution,” said Conselice. When galaxies orbit each other closely, dark matter acts as a brake.

“Think of the dark matter as a pool that the two [galaxies] are located in together,” said Conselice. “As each galaxy moves through it, like a boat, the dark matter particles produce a wake, and that will decelerate them and eventually lead to the two galaxies merging.”

This effect had already been shown in computer models – in models without dark matter but with modified gravity, the merger rate was seen to be lower. Now there is observational evidence that galaxies do indeed follow the dark matter scenario.

Conselice doesn’t claim that this clinches the case, but it comes close. “You have to really detect the particles for dark matter to be absolutely

The cores of two merging galaxies and their spiral arms

proven. But there are other ways of showing it probably does exist; we have many already, and this is another one,” he said.

Oliver Müller at the University of Strasbourg in France, an astronomer who compares dark matter and MOND theories, calls for caution. He would like to wait for computers to become fast enough to simulate the evolution of the universe under the MOND assumption, in order to see if the merger rates really are too low.

“We need to make sure the competition is fair,” he says. “When we know for sure it is fair and it’s disfavours MOND, that would be highly intriguing.”

Müller says that, on the scale of galaxies, MOND generally fits our observations better than dark matter theories, so “seeing [MOND] losing on its turf, where it’s supposedly best, is exciting”. ■

Astronomy

... while evidence for dark matter mounts in the Milky Way

Leah Crane

OUR galaxy has an enormous bar made of stars at its centre, from which its spiral arms emanate. That bar rotates, but the dark matter suffusing the Milky Way is slowing it down by about 13 per cent every billion years.

Rimpei Chiba at the University of Oxford and Ralph Schönrich at University College London used observations of stars from the Gaia space telescope to demonstrate the galactic bar’s gradual deceleration.

This was possible because some stars, rather than orbiting the centre of the galaxy, travel around what is called a Lagrangian point, where the gravity from the galactic bar and the outward push from its rotation balance to create a stable gravitational point.

The location of this point is dependent on the rotational speed of the galactic bar. If its rotation slows, the Lagrangian point moves outward, dragging along the stars that orbit it and picking up other, younger stars as it goes.

By measuring the ages of the stars in this resulting clump and using them like the rings in a tree stump, the pair of researchers determined that the Lagrangian point is moving outwards at a rate of about 2600 light years per billion years.

That translates to the bar’s rotation slowing by about 13 per cent per billion years (*Monthly Notices of the Royal Astronomical Society*, doi.org/ghkp).

It is another piece of evidence that dark matter is real, says Schönrich. Ideas that would explain away other effects of dark matter through modifications to the theory of gravity (see “Dark matter rival fails key galaxy merger test...”, left) cannot explain the drag on the bar.

“Our result is bad for those theories and, in the future, it could constrain dark matter models,” says Schönrich. ■

Climate change

Airlines lobby against green plans

A new report finds some European airlines have been challenging EU climate policies

Adam Vaughan

SEVERAL European airlines have been engaged in wide-ranging lobbying to challenge European Union climate policies, a UK-based think tank has found.

InfluenceMap, a think tank that monitors corporate lobbying around climate change, used freedom of information requests and research to draw up its report.

It reveals that while the 10 European airlines looked at for the report have received around €30 billion in government bailouts during the pandemic – some of which came with conditions attached to encourage climate-friendly actions – most have lobbied to delay new proposals to cut aviation emissions.

Air France-KLM, IAG (the parent company of British Airways), Lufthansa and Ryanair – Europe's four biggest airlines by emissions – were found to be the most regressive in their stance towards climate policies. The report rated their position roughly on a par with the airline trade bodies IATA and Airlines for Europe (A4E).

Ben Youriev, the report's author, says the unity of opposition across

the sector is “startling” compared with most other industrial sectors.

IATA labelled the report “a gross distortion of the aviation industry's genuine and long-standing sustainability efforts”.

According to the report, one of the most significant lobbying targets was repeated attempts by IATA and A4E to persuade the European Commission (EC) to address emissions from

A Lufthansa Airbus A340-300 waiting to take-off at an airport in Germany



CLYNT GARNHAM AVIATION/ALAMY

international aviation from the mid-2020s through a global carbon offsetting scheme, CORSIA, rather than the EU's own carbon market, the ETS. The EC has previously concluded that, in several respects, CORSIA was “less ambitious than the regulation of aviation within the EU ETS”.

Lufthansa responded to the report by stating that “[o]nly strong and competitive companies are in a position to invest in new technologies and further climate protection measures. In Germany,

for example, airlines are burdened threefold by the aviation tax, the ETS and CORSIA, while airlines from Turkey, the Gulf states and Asia operate under completely different environmental and social standards.”

The InfluenceMap report also shows that airlines lobbied against EC plans to announce a mandate on their use of sustainable aviation fuel, made from animal waste and cooking oil.

The biofuels are seen as a key short-term way to bring down aviation emissions. Emails obtained by InfluenceMap through FOI requests reveal Lufthansa warned the EC in January and February that the mandate could undermine a “level playing field between European and non-European airlines”.

A4E said in a statement that the report fails to reflect the collective actions and investments made by European airlines to address climate change. Other companies mentioned in the report hadn't responded to a request for comment at the time of publication. ■

Evolution

Many female animals evolving to look more attractive

SEXUAL selection, a mechanism of evolution that can drive the appearance of bright feathers and elaborate horns, is often assumed to operate largely among males. But a fresh look at the data suggests it is more widespread among females than many researchers expected.

It was Charles Darwin who originally suggested that males often compete against other males

for females to mate with – which he argued could help explain why, for instance, some male birds have developed bright plumage even though this makes them a more obvious target for predators.

More recently, biologists have begun to realise that sexual selection operates widely among females too, although Tim Janicke at the Centre for Functional and Evolutionary Ecology in France and his colleagues say it is still assumed to be a rare peculiarity.

Now, Janicke and his colleagues have collected evidence of female-orientated sexual selection

in 72 species across the animal kingdom from scientific literature published between 2015 and 2020. They say the analysis suggests that competition for mates in females should be considered the norm (bioRxiv, doi.org/ghjt).

“We believe that our view of how we see sex differences in general, and also sexual selection in particular, is still very biased towards males,” says Janicke.

“Our view of how we see sex differences and sexual selection is still very biased towards males”

The analysis shows evidence of female sexual selection in a broad range of animals. For example, in various species of pike, it is the female that is more colourful, with more stripes to attract mates. And in some tropical wading birds, such as jacanas, females fight each other for the attention of the highest quality male. The researchers invite investigators to spend more time studying such behaviour in females.

“Sexual selection is a process that may affect any sex,” says Ingrid Ahnesjö at Uppsala University in Sweden. ■

Karina Shah

A powerful quantum microscope

Squeezing light to illuminate samples lets us view living cells in unprecedented detail

Leah Crane

MICROSCOPES used to image living systems have made a quantum leap. Using a quantum trick with light has allowed researchers to examine cells in remarkable detail without destroying them, a technique that could improve medical diagnoses and microbiology research.

The microscopes that are generally used to examine such biological systems shine one or two bright lights on their targets, and more powerful light sources allow researchers to see the cells in greater detail. But this approach has a fundamental limit to the precision it can achieve: at some point, a bright enough light will kill a living cell.

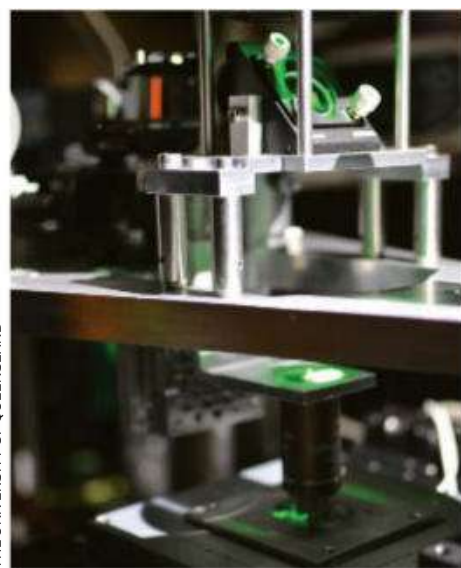
“Our understanding of life as it is now has relied almost entirely on the quality of our microscopes,” says Warwick Bowen at the University of Queensland in Australia. “We’re really limited by technology, and it’s not obvious how to break the existing limits because we’ve already pushed the intensity as high as we can without destroying the cell.”

Bowen and his colleagues have

found a way to overcome this problem. They used a type of microscope with two laser light sources, but sent one of the beams through a specially designed crystal that “squeezes” the light. It does so by introducing quantum correlations in the photons – the particles of light in the laser beam.

The photons were coupled into correlated pairs, and any of them that had energies unlike the others

Laser light squeezed through a crystal produces sharper microscope images



THE UNIVERSITY OF QUEENSLAND

were discarded instead of being paired off. That process lowered the intensity of the beam while decreasing its noise, which allowed for much more precise imaging.

“When you decrease the intensity you decrease the noise as well – you’re not [randomly] throwing away these photons, you’re shuffling them into pairs,” says Bowen.

When the researchers tested their system, they found that they were able to make measurements that were 35 per cent sharper than a similar device that didn’t use squeezed light (*Nature*, doi.org/gkhdzr).

“In order to achieve this kind of measurement without quantum correlations, you’d have to turn the intensity up,” says Bowen. “But if you turned up the intensity enough to match these results, you’d destroy the sample, so we’re able to examine things that previously would have been impossible to see.”

These included the wall of a yeast cell (*Saccharomyces cerevisiae*), which is about 10 nanometres thick, as well as the

fluid within a cell, both of which would be faint even with the best non-quantum microscopes, and completely invisible with standard microscopes. Observing these minuscule parts of living tissues could help us understand the basics of life at smaller scales.

“This is a very exciting advance in the field of optical microscopy that opens the door for improving how state-of-the-art microscopes can work, at light intensities that are right at the threshold of damaging biological samples,” says Frank Vollmer at the University of Exeter in the UK.

The squeezed light technique is also used to reduce noise in other laser-based scientific instruments, such as those used to detect cosmic gravitational waves.

Quantum microscopes will also have practical applications, says Bowen. For example, light-based microscopes are often used to determine if cells are cancerous or to diagnose other diseases, and squeezed light could significantly improve the sensitivity of those tests as well as speeding them up, he says. ■

Computing

Google AI designs chips to make AI more efficient

ENGINEERS at Google have tasked an artificial intelligence with designing faster and more efficient processors – and then used its chip design to develop the next generation of computers that run the very same type of AI algorithms.

One stage of chip design is called floorplanning, which involves taking the finalised circuit diagram of a new chip and arranging the millions of components into an efficient

layout for manufacturing. Although the functional design of the chip is complete at this point, the layout can have a huge effect on speed and power consumption.

Floorplanning has previously been a highly manual and time-consuming task, says Anna Goldie at Google. Teams would split larger chips into blocks and work on parts in parallel, fiddling around to find small refinements, she says.

But Goldie and her colleagues have used a neural network to take a different approach, treating a blank chip and its millions of components as a jigsaw with

a vast amount of possible solutions.

The software first developed solutions at random that were tested for performance and efficiency by a separate algorithm and then fed back to the first one. In this way, it slowly learned what strategies were effective and built on past successes (*Nature*, doi.org/gkhhgd).

“It started off kind of random and gets really bad placements, but after thousands of iterations

“The AI started off random and really bad, but after thousands of iterations it becomes extremely good”

it becomes extremely good and fast,” says Goldie.

The software produced layouts in under 6 hours that were comparable or superior to those created by humans over several months in terms of performance, power consumption and chip density.

The new AI-designed chip is the latest version of Google’s Tensor Processing Unit, which runs neural network algorithms for use in its search engine and automatic translation tool. It is conceivable that this new chip will be used in the future to design its successor. ■

Matthew Sparkes

Astronomy

Mysterious radio signals blast all over the cosmos

Jonathan O'Callaghan

EVERY day, thousands of mysterious radio signals flash across the universe, astronomers have found.

First discovered in 2007, these fast radio bursts (FRBs) are extremely bright flashes of radio waves that last just milliseconds and seem to occur across the universe. We still don't know what causes most of them, but ideas include neutron stars with particularly strong magnetic fields, known as magnetars, or perhaps binary stars interacting in unusual ways.

Until 2018, FRBs had been notoriously tricky to find because of their short duration, meaning there were only 140 on record. But the Canadian Hydrogen Intensity Mapping Experiment (CHIME) telescope came online that year, and now researchers working on it have announced a new catalogue of many more FRBs.

"In one year, we have detected 535 FRBs," says Mohit Bhardwaj at McGill University in Canada, a member of the CHIME team, who presented the work at a virtual meeting of the American Astronomical Society on 9 June. "We have almost quadrupled the amount of FRBs that were previously known."

The discoveries were made between July 2018 and July 2019, with 18 of the 535 bursts also found to be repeating signals. CHIME's view sweeps across the entire sky every day to hunt for FRBs, but complex analysis is needed to identify them among the other noise in the instrument, with about 7 terabits of data produced every second (arxiv.org/abs/2106.04352).

The catalogue allowed the team to estimate that there should be 9000 FRBs visible every day in the sky. CHIME's narrow view only allows it to see a fraction of these at a time. ■

Genetics

How a honeybee cloned itself hundreds of millions of times

Christa Lesté-Lasserre



CATHY WITHERS-CLARKE/ALAMY

A Cape honeybee foraging in flowers in southern Africa

recombination that were 100 times greater than seen in the cloned offspring of the worker bees.

In fact, the worker bees' offspring were essentially perfect copies of their mothers, says Oldroyd, which suggests that the Cape worker bees have evolved a mutation that effectively prevents genetic recombination during reproduction (*Proceedings of the Royal Society B*, doi.org/gkgxjs).

One line of clones has been re-cloning since 1990, with the same individual copied hundreds of millions of times, says Oldroyd.

The clones can prove problematic for the health of the colony, however. Generally speaking, the queen bee is the only individual that reproduces, while other bees carry out their own duties to keep the colony healthy.

If the workers begin cloning themselves – which can happen if the hive is disturbed in some way – this delicate balance is destroyed. In some cases, one of the clones can even develop into a queen of a dysfunctional hive.

"Eventually, the workers just sort of hang around laying eggs not doing any work," says Oldroyd. "The colony dies, and [the cloning workers] spread to the next colony."

Even after these workers have invaded a new colony they continue to lay eggs, disrupting and potentially taking over that colony too.

"They kill about 10 per cent of South African colonies every year. It's like a transmissible social cancer," says Oldroyd. ■

THE workers of a South African subspecies of honeybee can clone themselves, with one individual having done so many millions of times over the past 30 years. Some of the clones can even develop into queens that can take over the hive.

Asexual reproduction – parthenogenesis – isn't uncommon in the insect world, but having offspring that are genetically identical to the parent is. That is because, during the reproductive process, genetic material gets mixed up in a process called recombination. As a result, even if there is only one parent, its offspring end up with a slightly different genetic make-up.

However, the female workers of the Cape honeybee (*Apis mellifera capensis*), native to southern South Africa, have developed the unusual ability to clone themselves while effectively avoiding recombination during reproduction, says Benjamin Oldroyd at the University of Sydney, Australia.

Doing so carries important benefits. Normally, asexual reproduction can be lethal

in honeybees because about a third of the genes become inbred, and the larvae don't survive, says Oldroyd. But a Cape honeybee worker clone remains as genetically healthy as her mother. "It's quite remarkable," he says.

Curious about how the worker clones maintain such strong genetic integrity without

31

Years it has taken one bee to give rise to millions of clones

inbreeding, Oldroyd and his colleagues compared the genomes of Cape worker bees, Cape virgin queens and their offspring. Cape queens generally reproduce sexually, so to force them to reproduce asexually, the scientists fitted them with a strip of surgical tape glued with nail varnish to prevent them mating.

The researchers genotyped one queen and 25 of her larvae, and four workers and 63 of their larvae.

They found that the asexually produced offspring of the queen showed levels of genetic

Space

Vast black holes clear way for some galaxies to thrive

SUPERMASSIVE black holes in large galaxies may be a boon for nearby, lesser galaxies. Many big galaxies are orbited by smaller ones, and now it seems the hosts' central black holes can boost the life cycles of some of these satellites.

Ignacio Martín-Navarro at the Institute of Astrophysics of the Canary Islands in Spain and his team examined 124,163 satellite galaxies observed by the Sloan Digital Sky Survey. They looked at which were "quenched", meaning they were no longer forming stars.

Some central black holes called active galactic nuclei (AGNs) have vast outflows of energy perpendicular to the plane of their galaxies, and these winds are powerful enough to affect the nearby satellite galaxies.

The team found that the satellites

that orbited closer to the plane of their host galaxies were more likely to be quenched than those that orbited at an angle. "We actually were expecting for the satellites that were not in the host galaxy's plane to be damaged by the AGNs," says Martín-Navarro. "But we found the opposite effect."

This may be because, rather than blasting the gas required for star formation out of the satellite galaxies, these winds tend to create bubbles of space that are less dense than the surrounding areas.

The satellites that pass through these bubbles aren't ramming through the dust and gas that normally fill the space near galaxies, which can strip away the gas needed for star formation, thereby quenching galaxies (*Nature*, doi.org/gkhh47). Leah Crane

Health

Laughing gas could help ease depression

NITROUS oxide, also known as laughing gas, has shown promise for treating depression.

It has long been known that nitrous oxide, also used as an anaesthetic, can give a short boost to mood, but it wears off quickly.

The gas seems to chiefly affect the brain by blocking molecules on nerve cells called N-methyl-D-aspartate (NMDA) receptors. This is the same thing targeted by the stronger anaesthetic ketamine, which also relieves depression.

It isn't known how NMDA receptors change mood. But as the antidepressant effects of ketamine started to emerge, Peter Nagele, then at Washington University School of Medicine in St Louis, Missouri, wondered if nitrous oxide had similar potential.

In 2014, he and his team found that 1 hour's inhalation of nitrous oxide reduced symptoms for up to

a day in people with depression that hadn't improved after using standard antidepressant drugs, but the study didn't record whether the effect lasted any longer.

Prolonged nitrous oxide use can lead to nausea and headaches. So, in the latest study, Nagele's team looked at 24 people with treatment-resistant depression and gave them half-dose nitrous oxide, a full dose or a placebo. They were given one treatment a month for three months.

After two weeks, depression symptoms for those with the half-dose treatment had reduced by an average of five points on a depression rating scale, compared with those who had the placebo. After the full dose, symptoms reduced a little more, although the difference was so small that it could have arisen by chance. The half-dose group had a much lower incidence of side effects, such as nausea and headaches (*Science Translational Medicine*, doi.org/gghx). Clare Wilson

Environment

Less e-waste piled up during pandemic

THE pandemic has caused a slump in electronic device sales and a fall in related waste, UN researchers have found. This may provide an opportunity for governments to improve e-waste recycling.

In 2019, there were 53.6 million tonnes of e-waste globally – old electronics that can contain toxic substances, such as brominated flame retardants, lead and mercury. East and South-East

Asia accounted for over 22 million tonnes of this, while Europe and North America generated slightly less than 20 million tonnes.

Despite more laptops and games consoles being bought, the sale of electronic equipment worldwide fell by 6.4 per cent in the first nine months of 2020 compared with sales estimates based on previous years.

There was a 30 per cent fall in sales in low and middle-income countries, but only a 5 per cent decline in high-income nations.

The overall drop translates to 4.9 million tonnes less electronic waste in the first nine months of 2020, says a report from the UN, which suggests that nations use this as an opportunity to improve e-waste management.

Report co-author Kees Baldé at the United Nations University in Tokyo says that while this gives a bit of breathing space, the world must increase recycling more than fivefold to properly deal with e-waste. Matthew Sparkes

NASA/SOFIA/LYNETTE COOK



ZORAN MILICH/GETTY IMAGES



Really brief



WATERFRAME/ALAMY

Reefs face tipping point by 2054

Coral reefs could start to disappear in a few decades. The rate at which they are depositing new calcium carbonate is dropping by around 4 per cent a year because of ocean acidification. By 2054, coral reefs may erode faster than they regenerate (*Communications Earth & Environment*, doi.org/gghhf).

Your ears can reveal if you are drunk

A new device captures alcohol given off by the skin of a person's ears. It can measure the amount of alcohol in their blood and whether they are over a legal limit. The earmuff-like device records a similar rise and fall in alcohol levels as a breathalyser, but with a 1.3-minute delay (*Scientific Reports*, doi.org/gghhg).

Building blocks for life at galaxy's edge

Telescopes have spotted organic molecules such as methanol in gas clouds at the edge of the Milky Way, even though carbon and oxygen are rare there. The results, presented at a virtual meeting of the American Astronomical Society, suggest this region may be more hospitable to life than we thought.

Palaeontology

Early land dwellers returned to water

ONE of the greatest evolutionary transitions was the emergence of tetrapods, or four-legged vertebrates, onto land about 340 million years ago. But an analysis of some early tetrapods now suggests that not long after this, some species became adapted to life in the water all over again.

Aja Mia Carter at the University of Pennsylvania and her team focused on early amphibians called temnospondyls, roughly

salamander-like tetrapods that spun off many species between 295 and 330 million years ago.

Rather than looking at the limbs of these animals, though, the team analysed the backbone anatomy of over a dozen temnospondyl species. It also used a previously published evolutionary tree to understand how these species were interrelated, and searched earlier studies for information on the likely lifestyles of each – in particular whether it was either more aquatic or terrestrial.

The researchers found that temnospondyls probably evolved

from a land-dwelling ancestor. Surprisingly, from there, some species changed course and became adapted to life in water all over again in an evolutionary reversal.

The analysis also revealed that relatively stiff backbones weren't an adaptation to life on land. Researchers have typically assumed that early land animals evolved a stiffer spine to help support their bodies, but it was actually the water-dwelling temnospondyls that had a more rigid spine (*PLoS One*, doi.org/gkhhp). **Riley Black**

Natural disasters



IRFAN RASHID, DEPARTMENT OF GEOINFORMATICS, UOK

Cause of deadly flood in Indian valley pinned down

A FLOOD in Uttarakhand, India, that left more than 200 people dead or missing resulted from an avalanche that dropped about 27 million square metres of rock and glacier ice from the nearby Ronti mountain.

On 7 February 2021, residents of Chamoli district saw a plume of dust coming down the valley followed by a vast amount of water that hit two hydropower sites. Many people caught the dramatic event on video.

Dan Shugar at the University of Calgary, Canada, and his colleagues used satellite images and sensor data to trace the source of the flood. They found that it was triggered by an avalanche consisting of about

80 per cent bedrock and 20 per cent glacier ice that dropped to the valley almost 2 kilometres below, then continued down, picking up more debris (*Science*, doi.org/gkh2nd).

"During that descent of something like 3400 metres, the frictional energy that was released in the form of heat was able to melt almost all of the glacier ice and that... produced all the water that we see in those videos," says Shugar.

It is unclear if climate change played a role in the disaster, says Marta Chiarle at the Research Institute for Geo-Hydrological Protection in Turin, Italy.

Krista Charles

Animals

Super cetacean went on a globetrotting trip

A WHALE spotted off the coast of Namibia swam halfway around the planet to get there – setting a record for a migration of any mammal, barring humans.

The lone gray whale (*Eschrichtius robustus*) was seen there in May and July of 2013. This was odd, as while there have been rare sightings of the species in the Atlantic Ocean, these whales are usually confined to the northern hemisphere.

Now Rus Hoelzel at Durham University in the UK and his team have used tissue samples from the whale's skin to analyse its DNA and trace its origins.

By comparing it with other grey whale populations, they found that this individual, a male, was probably born to the endangered western North Pacific population, found along the coast of eastern Asia. This means it travelled at least 20,000 kilometres to get to the southern Atlantic (*Biology Letters*, doi.org/gghjr).

While it is impossible to know for sure how this whale got to the southern Atlantic, the team has proposed three possible routes – it could have headed north through the Arctic, south around South America, or along Asia and around Africa. **KC**

ONLINE EVENT

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Dame Wendy Hall
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University of Southampton

Nick Jennings
Professor of Artificial Intelligence,
Imperial College London

Dave Short
Technology Director,
BAE Systems

Justin Mullins
Consultant Editor,
New Scientist and debate chair

The columnist

James Wong on the fickle nature of some modern diets **p24**

Aperture

Threads of energy at the heart of the Milky Way **p26**

Letters

Why switch to hydrogen when nuclear will do? **p28**

Culture

A Malawian climate activist takes the fight to the US **p30**

Culture columnist

Simon Ings has a look at multiverse thriller *Parallel* **p32**

Comment

The trouble with calories

The calories on food packets are wrong. It is time we demanded better information on what we consume, says **Giles Yeo**

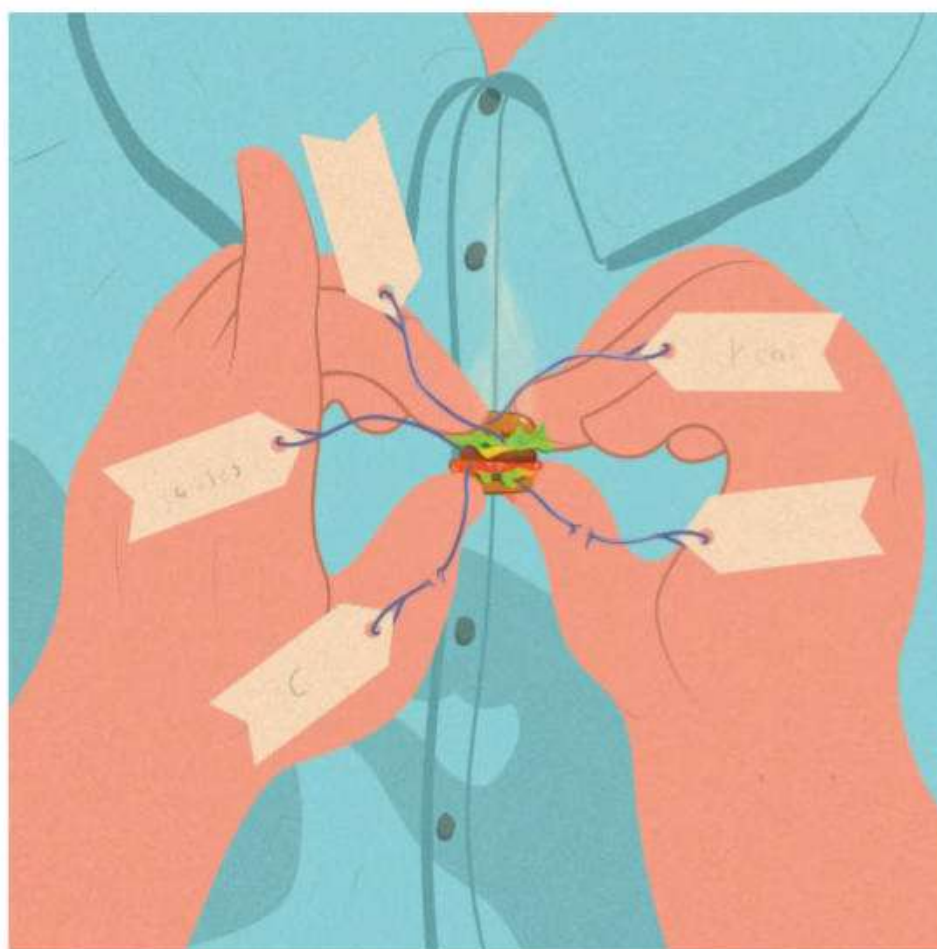
A CALORIE is a calorie, so they say. It shouldn't matter whether it comes from steak, a carrot or a doughnut. Except that it does. And those calorie counts on food packets? Well, they aren't much to be trusted either.

A food calorie is defined as the amount of energy it takes to raise the temperature of 1 litre of water by 1°C at sea level. Somewhat confusingly, this is 1000 times larger than a heat calorie, so is technically called a Calorie, with a big "c", to make the distinction. In other words, a Calorie is a kilocalorie, or kcal for short.

Much of what we know about food calories comes from work in the late 1880s by Wilbur Atwater at Wesleyan University in Connecticut, who spent his career trying to figure out what proportion of different foods humans could digest. To measure the calories in food, Atwater set up an experiment using a "bomb calorimeter"—a highly pressurised sealed container that is filled with pure oxygen for burning food to a crisp. The heat given off during this is used to calculate the food's calorie content, which is also known as its heat of combustion.

Humans, however, aren't bomb calorimeters. The acidic cauldron of the stomach aside, digestion is a time-consuming, but actually relatively benign, series of chemical reactions. Thus, we are only able to extract a proportion of the calories in any given food.

In Atwater's experiment,



he fed various foods to human volunteers and measured the heat of combustion of the resulting faeces (reflect on this the next time you want to complain about your job). By calculating the difference in the heat of combustion between the food and the faeces, he approximated the calories that were absorbed by his volunteers.

In 1900, after a whole lot of burnt poop, Atwater presented his calculations to the world: we absorb 9 kcal per gram of fat, 4 kcal per gram of carbohydrates and 4 kcal per gram of protein. More than 120 years on, these

"Atwater factors" are still the basis for how calorie counts on all food packaging are derived.

Yet, they are wrong. By the 1970s, it was clear they weren't adding up. While Atwater took into account the fibre in food, which we can't digest (hello sweetcorn), as well as the nitrogen extracted from protein and excreted as urea in our urine, he didn't take into account the heat given off during metabolism. This is known as diet-induced thermogenesis and is the significant energy cost of converting protein, fat and carbs into the amino acids, fatty acids and glucose that our body needs.

Protein has a caloric availability of 70 per cent, meaning that for every 100 kcals of protein that makes it into the bloodstream, we are only able to use 70 kcals, with the other 30 kcals given off as heat from diet-induced thermogenesis.

By comparison, fat has a caloric availability of 98 per cent, hence why it is such an efficient long-term fuel store. As for carbs, it depends on whether we are talking about the complex (90 per cent availability) or refined (95 per cent) variety. This, in part, is why a calorie of protein makes you feel fuller than a calorie of fat or carbs.

In 2001, consultant Geoffrey Livesey coined the term "net metabolisable energy" to describe the concept of caloric availability, and proposed replacing the Atwater factors on food labels. But it was ignored by the food industry and gained no traction.

In a world where much of the burden of non-transmissible illnesses is diet-related, we need to have a better understanding of the quality of our food and that begins with the labels on packets. So 20 years on, this is me picking up the baton from Livesey and trying to push caloric availability into the conversation. It does indeed matter whether a calorie comes from steak, a carrot or a doughnut. We just need the right information to be able to judge. ■



Giles Yeo is at the University of Cambridge. His book *Why Calories Don't Count* is out now

#FactsMatter

The fickle nature of diets There has been a sharp change in what some people consider healthy to eat and a lot of it flies in the face of the evidence, writes **James Wong**



James Wong is a botanist and science writer, with a particular interest in food crops, conservation and the environment. Trained at the Royal Botanic Gardens, Kew, he shares his tiny London flat with more than 500 houseplants. You can follow him on Twitter and Instagram @botanygeek

James's week

What I'm reading

Studies about our cultural relationship with nature, to prepare for a BBC arts programme this year.

What I'm watching

The amazing Adam Curtis documentary Can't Get You Out of My Head, on the emotional history of the modern world.

What I'm working on

A new season of my BBC Follow the Food series, looking at new ways to fight food waste.

This column appears monthly. Up next week: Chanda Prescod-Weinstein

IN OUR information-saturated digital age, where we can pick and choose our own narrative about how the world works, I have often wondered if this has an impact on the rate of cultural change. As an ethnobotanist trained to study our cultural attitude towards plants and their uses, I have been witnessing with total fascination what seems to be a rapid shift in how plants are viewed in received nutritional wisdom. I wonder if this may be a sign of things to come.

I first noticed the trend about 15 years ago with the emergence of the “paleo” diet movement. This largely repackaged ideas from the ultra-low carbohydrate diets that came before it, but underpinned them with a “return to nature” narrative. According to the paleo school of thought, in order to be truly healthy, we need to eat as our hunter-gatherer ancestors did, ditching as many carbohydrates as possible. This meant a diet based predominantly on meat, with a few low-carbohydrate vegetables like leaves, stems and flowers. Pretty much all fruit, however, was off limits due to its sugar content.

Many questionable justifications have been used to support this. For instance, in our deep Palaeolithic past, fruit was available, but highly seasonal. So, the argument went that, while consuming restricted amounts in a short window in the summer was fine, today's hyperabundance and year-round availability was the root cause of chronic diseases.

It might be easy to dismiss these ideas as only belonging to a particularly devoted set of niche dieters. However, such thinking quickly started popping up in different guises in the mainstream and even, albeit in a diluted form, as government health advice in some places.

What is interesting about the paleo diet idea to a botanist is that it assumes all early humans lived in the world's temperate zones where fruit is seasonal, as (perhaps unsurprisingly) do the creators of these diets. It is almost like humans aren't a species that evolved in the tropics at all. This Western-centric focus is often extended to the idea that you should specifically avoid “tropical” fruits as they are higher in sugar.

That is another curious claim, as there doesn't appear to be any data that supports the generalisation. In fact, the highest sugar fruits I can think of, like dates and grapes,

“If we are only meant to eat things that ‘want’ to be eaten, I have really bad news for meat lovers”

aren't tropical, but temperate in origin. That is before we consider that animals in temperate climates are subject to seasonal availability too. Think of bird eggs and spawning salmon. Does that mean we should avoid these too?

So it was an enormous surprise that, over the past few months, leading lights in the paleo and carnivore diets community have seemingly reversed some of their most central beliefs about plant foods. Several are now saying that adding fruit to their diets over the pandemic has transformed their health, including many who claimed cutting out fruit had the same effect just a year or two ago.

To justify this change of heart, they are pointing to (actually often very sound) evolutionary reasoning, such as our excellent red-green colour vision compared with that of many animals, which is thought to allow us to detect

ripe fruit faster. Voices that once described fruit as “bags of sugar” are now pointing to our instinctive preference for sweet flavours as justification for eating it.

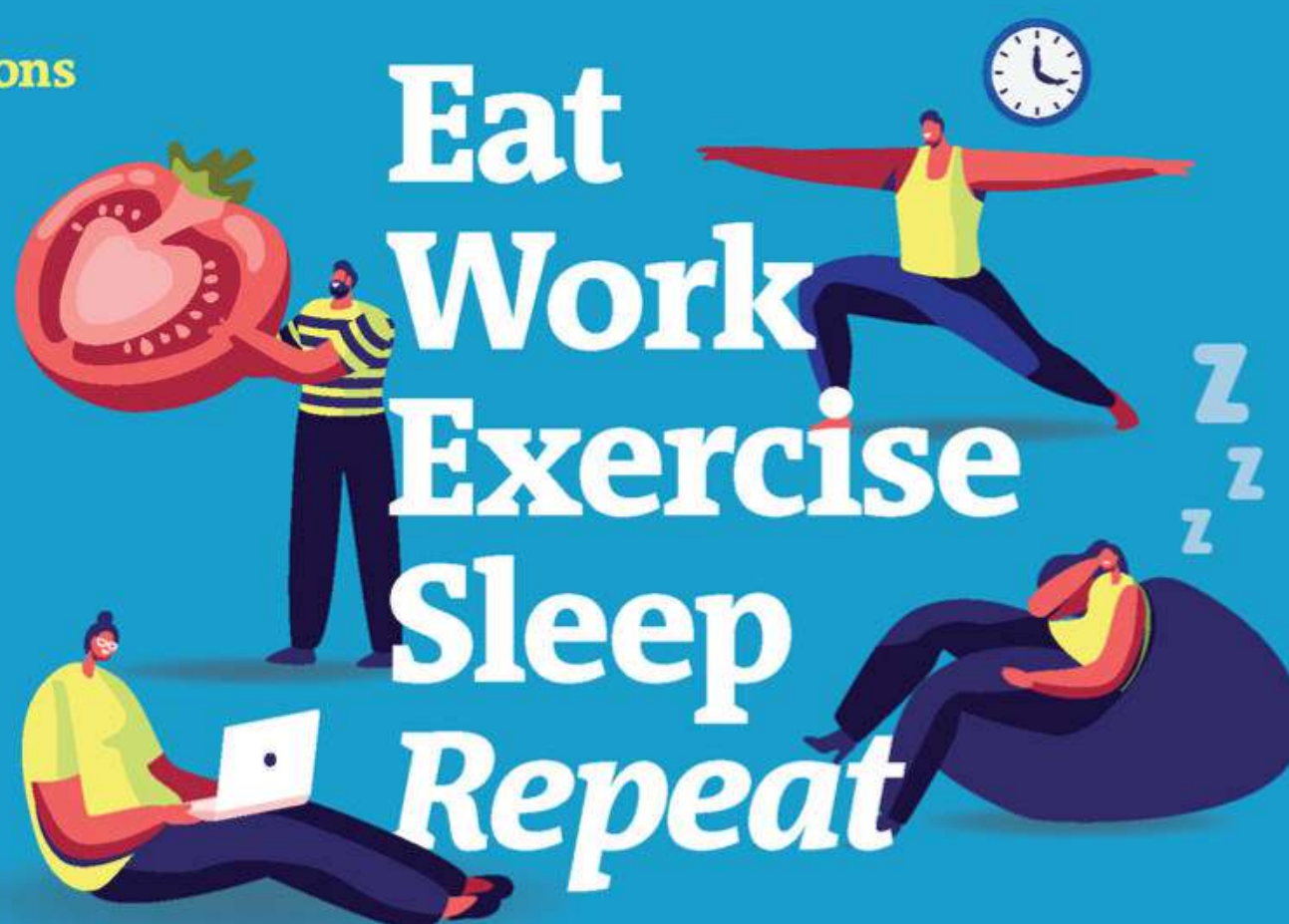
From a scientific point of view, this cultural shift all seems like a positive step. That is because the research consensus is that consuming fruit is beneficial for our health, but the vast majority of us aren't eating enough of it.

However, cultures are funny things. The fruit U-turn seems to have coincided with some paleo diet devotees calling for the exclusion of vegetables. It is now argued that these are full of potentially toxic compounds designed to deter herbivores, and so can be harmful to our health. Appealing to imagined ideas of human evolution, proponents are now arguing that fruit is safe as plants “want” these parts to be eaten in order for the seeds they contain to be spread around in faeces, hence they don't contain these toxic compounds.

Leaving aside the fact that the distinction between “fruit” and “vegetable” isn't based in any kind of botanical reality, but is just a cultural quirk, it is true to say that many common edible plants do contain toxic compounds. Yet these are at very low doses for us and toxicity is dose dependent. More fundamentally, if we are only meant to eat things that “want” to be eaten, I have really bad news for anyone who consumes meat.

In the past, profound dietary shifts like this could take decades, even centuries to take hold. However, in the internet age, they seem to be unfolding in a matter of months. Given how quickly radical ideas can diffuse into more mainstream culture, I wonder if we'll see them become widely accepted in years to come, despite the lack of evidence. ■

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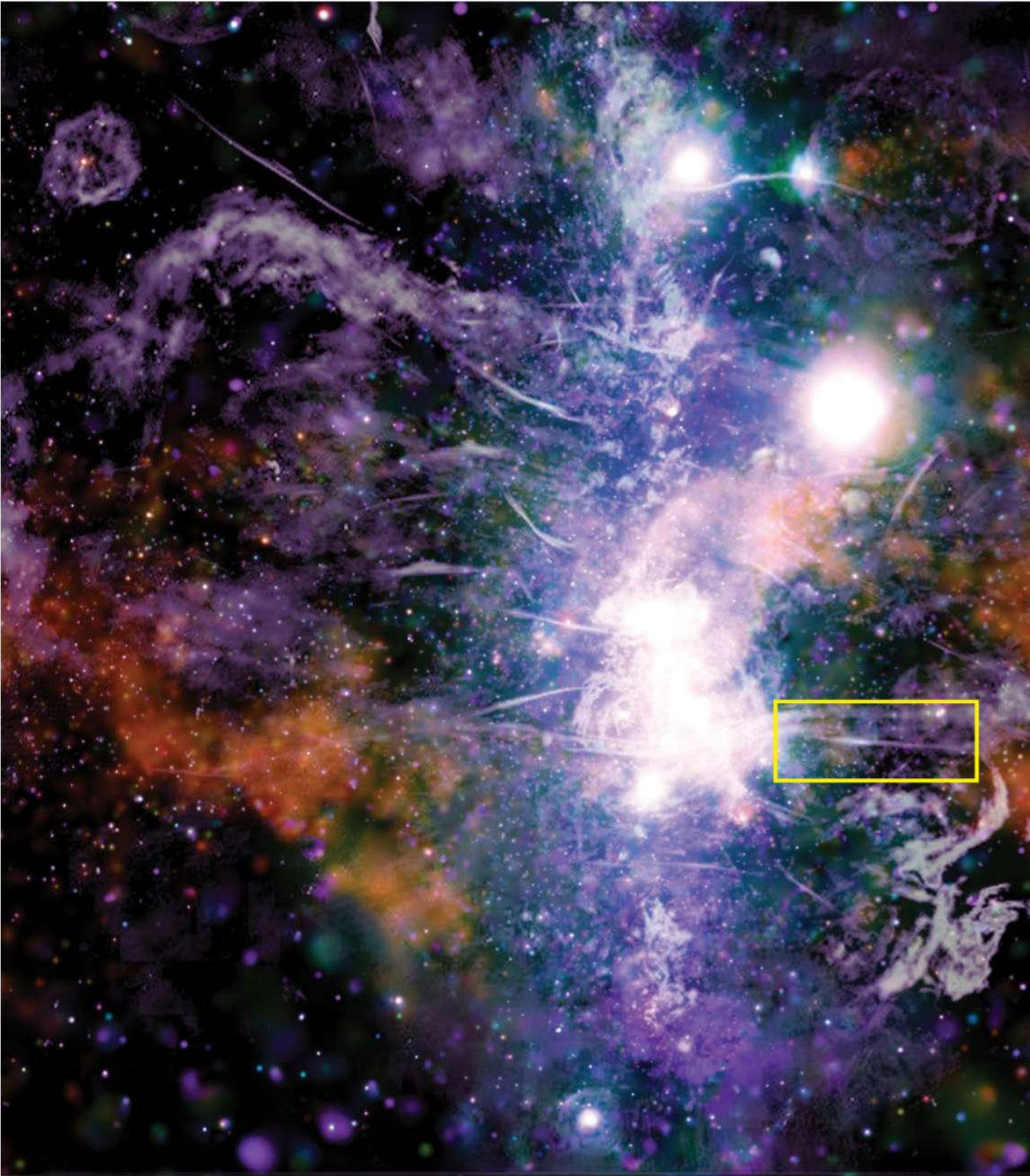
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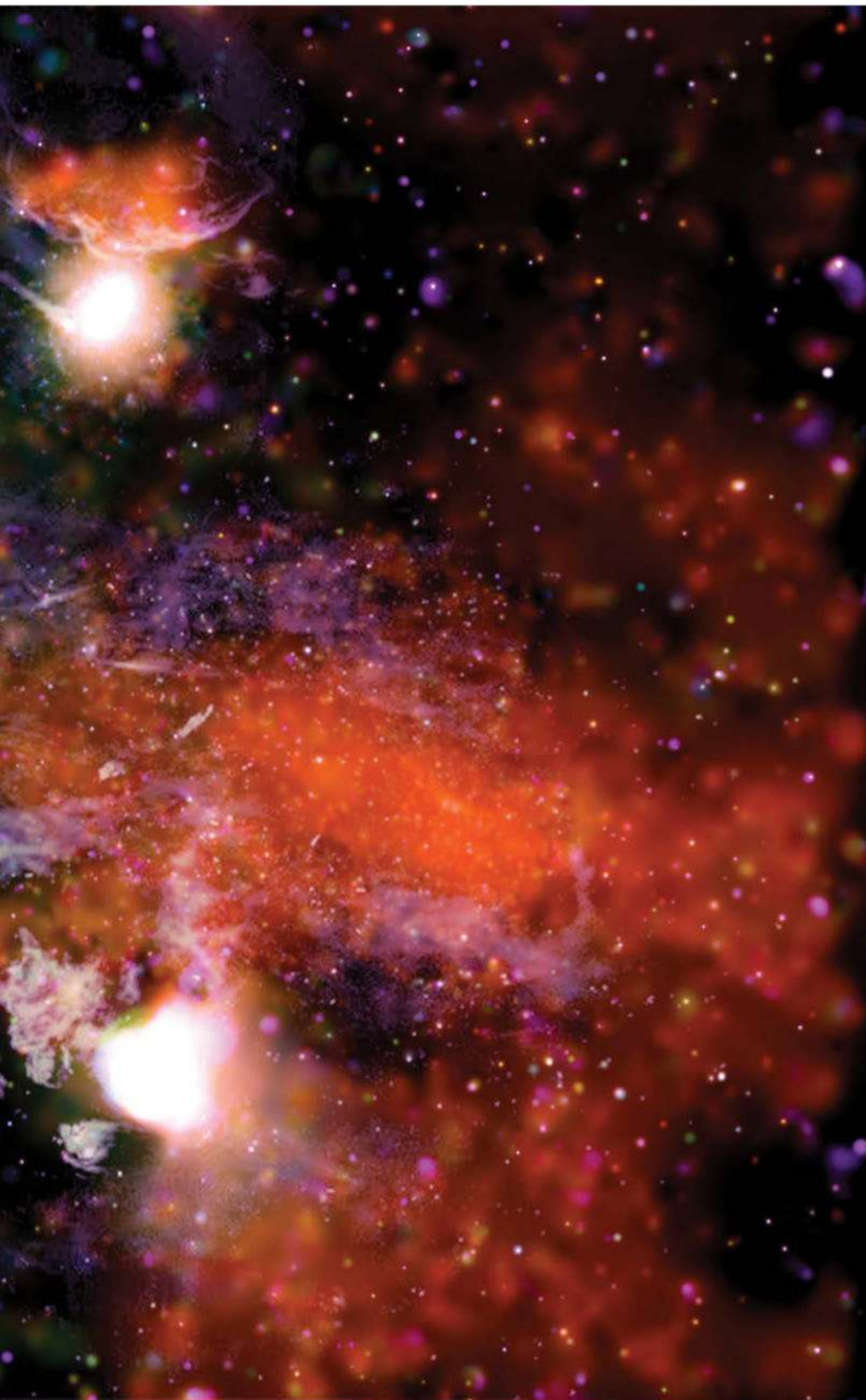
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Cosmic art



**Source X-ray: NASA/CXC/UMass/
Q.D. Wang; Radio: NRF/SARAO/
MeerKAT**

POWERFUL threads of energy interweave at the heart of the Milky Way in this spectacular image released by NASA. It is designed to give a broader view of the centre of our galaxy and provide insight into solar weather.

The image was created using data from two telescopes: NASA's Chandra X-ray Observatory, orbiting up to 139,000 kilometres above Earth, and the MeerKAT radio telescope in South Africa.

White threads denote superheated gas and magnetic fields. X-rays detected by Chandra from super-hot sources like exploded stars show as blue, green, orange or purple, depending on the energy of the radiation, while radio waves detected by MeerKAT are lilac and grey.

The thread marked by a rectangle is around 20 light years long, the equivalent of 189 trillion kilometres, and is especially interesting. It consists of both X-ray and radio emissions, which astronomers think could be bound together by thin strips of magnetic field, formed by a process in which magnetic fields collide and twist round each other.

This process is called magnetic reconnection, and it helps drive space weather, a phenomenon also created by activity on the sun's surface. Space weather can affect Earth by damaging satellites and causing electrical blackouts, so studying energy threads helps us better understand its impact. ■

Gege Li

Editor's pick

Why go for hydrogen when nuclear will do?

29 May, p 18

From John O'Neill,
Dunedin, New Zealand

In your look at Japan's promotion of a hydrogen economy to coincide with the Olympics, you mention the Suiso Frontier bulk carrier vessel, which will ship liquid hydrogen from Australia to Japan. It will carry 1250 cubic metres of the stuff, although some will boil off en route.

To illustrate the downsides, if a heavier element was chosen as a power source instead of the lightest, the same amount of energy could be transported in 10 kilograms of uranium pellets, which would fit easily in a handbag. Australia has the world's largest reserves of uranium, and Japan has around 30 nuclear reactors that are mothballed and whose output is being replaced by gas and coal.

On the role of capitalism in the climate emergency

Leader, 5 June

From Dave Holtum,
Bathampton, Somerset, UK

I was with you all the way in your leader on the need for change to tackle the climate emergency, and I also agreed with a lot of what Graham Lawton said in his article (p 40) about trying to make sure our pensions are invested in an ethical way that helps, rather than hinders, the drive to zero carbon.

But to suggest that "capitalism created climate change" is a step too far – people are responsible, not the economic or political system under which they exist. Attributing climate change to any particular "-ism" is a mistake and – partly, at least – absolves the individual from action.

From Peter Fattorini,
Conistone, North Yorkshire, UK
Your leader concludes that "capitalism created climate change". Sure, but only if you classify China and the

former Soviet Union as capitalist economies.

China is building more coal-fired power stations than the rest of the world combined and has plans for even more. As for the Soviet Union, take this analysis from Alexander Prishchepov at the University of Copenhagen in Denmark following its collapse: "The transition from a planned economy to a market economy had enormous consequences for food production and meat consumption. It led to a massive reduction in greenhouse gas emissions – the equivalent of up to 80% of the world's total CO₂ emissions from agriculture, forestry and other land use in 2010."

Capitalism certainly isn't blameless here. As you suggest, with legal backing, it can fix the problem – let's hope so.

From Merlin Reader, London, UK

Quite apart from the evidence suggesting we need a massive economic shift away from carbon emissions right now to have any chance of stopping runaway global warming, capitalism isn't about meeting people's needs, let alone environmental ones.

Economic growth is a tenet of capitalism and contradictory to the constraints of living on Earth. The statement that capitalism (including the state capitalist countries that claim to be socialist or communist) will do anything to significantly curb climate change in the timescale needed is wrong.

Let's invest in storage for the drive to zero carbon

5 June, p 13

From Chris Eve, Lynton, Devon, UK
The UK government seems wedded to colossally expensive power generation projects to

supply baseload electrical energy: first nuclear, now bioenergy with carbon capture and storage.

But it is energy storage, not baseload, that we need in the transition to renewable power. I wonder how feasible it would be to convert gas-fired power stations to burn hydrogen produced from wind or solar power, storing the hydrogen until needed?

Other ways to stay safe in the quantum era

29 May, p 36

From Robert Peck, York, UK

The quantum internet may not solve all our security problems. While any technology that reduces the ability of states and criminals to conduct surveillance and sabotage is to be welcomed, quantum communications are unlikely to be enough without a lot more technical work.

Another possibility is post-quantum cryptography. This still uses mathematics rather than photons, much like current cryptography, but aims to be resilient to the likes of encryption-busting methods in the quantum computer era, such as Shor's algorithm.

This has the advantage that it can easily work for stored data and over wireless radio links, neither of which have yet been proposed for quantum cryptography, which relies on real-time optical-fibre connections or precisely aimed laser link connections.

How to do your bit to save the insects

5 June, p 23

From Diane Tookey, London, UK
You report the sorry state of insect biodiversity. We could all do our bit to preserve insects by

making sure that, before disposing of cuttings and prunings in our gardens, we shake the foliage over the soil to release as many minibeasts as possible. It is surprising how many tiny animals can be seen to drop out.

This is why ancient black holes could be minnows

Letters, 5 June

From Eric Kvaalen,

Les Essarts-le-Roi, France

Michael Overholt wonders why a small primordial black hole wouldn't grow into a giant during the time when the universe was young. At that point, the universe consisted of gas or plasma that was fairly uniform. Although the black hole could attract gas near it, gas further away would have been moving fast enough to escape.

Get a measure of drink's role in civilisation today

5 June, p 30

From Bryn Glover, Kirkby
Malzeard, North Yorkshire, UK
Vijaysree Venkatraman's review of Edward Slingerland's book *Drunk: How we sipped, danced, and stumbled our way to civilization* got me wondering whether an analysis of recording devices placed in the bars of Magaluf in midsummer might prove useful for the future of humanity.

Even slackers can get motivated

29 May, p 41

From Susannah Matthews,
London, UK

The author of your piece on motivation has succumbed to hyperactivist propaganda and so gets the analysis (can't-be-) arse(d)-about-face.

As an unashamed slacker, there is nothing I like doing more than nothing. I am motivated and conscientious in my efforts to minimise the time wasted doing stuff. Writing to you on this important subject just makes the cut. ■



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Changing the climate mindset...

Anita Chitaya, a Malawian activist, travelled to the US to challenge views on climate change. Her story is fascinating viewing, says **Davide Abbatescianni**



Film

The Ants and the Grasshopper
Raj Patel and Zak Piper
Kartemquin Films

ANITA CHITAYA is an extremely determined person. A leader in the Malawian village of Bwabwa, she converts men to gender equality, fights to end child hunger and was ready to take on an impossible mission: travelling to the US to persuade then president Donald Trump that climate change is real and a threat to both rich and poor.

Chitaya is at the heart of *The Ants and the Grasshopper* by directors Raj Patel and Zak Piper, shown at the 2021 Sheffield Docfest this month. The film emerged from work by Patel, a professor in food systems at the University of Texas at Austin. It starts with Chitaya's life in Bwabwa, moves to her journey across the US in hope of accessing the White House, and ends with a short epilogue after her return.

The opening section makes the origins of Chitaya's gender work clear. After a tough childhood, she was forced into an "abduction marriage" by her husband-to-be Christopher, his friend Winston and a group of other men. She didn't feel she could fight because of a strong local belief that refusal to marry might have killed her mother.

Some time later, she met Esther Lupafya, an activist and nurse who co-founded a non-profit organisation called Soils, Food and Healthy Communities (SFHC), and her life changed. SFHC now works with more than 6000 farmers in northern and central Malawi, who exchange knowledge to improve soil fertility, food security and nutrition, and in the process encourage gender equity and



Anita Chitaya (bottom, centre) wants people to understand the impact of climate change

scepticism, as Patel and Piper struggle to make the links between gender inequality, poverty, racism and environmental issues explicit.

It is ambitious for a 74-minute film, and the directors take unwarranted shortcuts. We see only individuals on whom their encounter with Chitaya had a positive effect in the long term. In the epilogue, the farmworker from Wisconsin regrets laughing at Chitaya's concerns. He now runs an organic chicken farm, proving he has changed. We also learn that 18 months after her visit, Democrat senator Jeff Merkley co-sponsored the Green New Deal, although the impact of Chitaya's efforts is unclear. Merkley's office is as close as she gets to the White House.

The Ants and the Grasshopper attempts a fresh take on complex issues, but remains on the surface because it draws on too much material. It is the powerful portrait of Chitaya's courage, however, that makes the film worth watching.

In one of the last scenes, Winston pounds maize and joins a cooking demonstration, proving he has finally learned the value of caring.

But shortly after an image of a dead grasshopper borne away by ants, Chitaya says that many in the US don't fully understand what it means that "we live on the same planet as them"; there are many ants, but only a few lifting the grasshopper. A deeper focus on her fight against climate change and local inequality could have delivered a stronger message, but may not have been as messily truthful. ■

Davide Abbatescianni is a film critic based in Cork, Ireland

resilience against climate change.

Christopher seems to genuinely regret his past deeds and does his best to support Chitaya, but Winston stubbornly refuses to help his wife Jenifa cook, farm, water plants or do other chores seen as women's work. At SFHC, Chitaya learns more about climate change, convincing her neighbours to

"Many in the US don't fully understand what it means that we in Malawi live on the same planet as them"

build clay stoves and reduce their firewood use. Unsurprisingly, she accepts the directors' invitation to fly to the US with Lupafya.

During one early visit, to the village of Wonewoc, Wisconsin, Chitaya and Lupafya explain how climate change helped make their soil arid. One young farmworker argues that the world is undergoing a "weather cycle", refusing to accept the phenomenon's scale.

As it unfolds, the film shows encounters with farmers and activists both urban and rural, who in turn reflect awareness, advocacy, indifference or mild

... before it's too late

All life depends on nine natural processes – do we still have time to save them? **Elle Hunt** explores



Film

Breaking Boundaries: The science of our planet

Jon Clay

Netflix

FOR most of David Attenborough's 70-odd years on television, the question of life and death has been framed in terms of predator versus prey. It is only relatively recently that his documentaries have started to address the danger of the climate crisis confronting us all.

In last year's *David Attenborough: A Life on Our Planet*, the veteran broadcaster presented his "witness statement" on the environmental decline documented over his lifetime, pulling on political and personal levers to compel audiences to act. Now, in his latest film for Netflix, Attenborough focuses solely on the facts.

Breaking Boundaries is unusual among his considerable output for featuring little of Attenborough, and even of animals. Instead, its focus is squarely on the science of our planetary decline, setting out in unflinching detail the extent of Earth's degradation – and the catastrophic consequences of anything but drastic action.

Attenborough cedes the floor to Johan Rockström, the director of the Potsdam Institute for Climate Impact Research, to explain "the most important scientific discovery of our time". In 2009, Rockström identified nine natural processes upon which all life on Earth depends, and the limits within each that cannot be exceeded without endangering humanity.

This "planetary boundaries framework" serves as the structure

of the film. With support from Attenborough's voice-over and a global assembly of experts, Rockström details the impact of anthropogenic change on the nine processes, and where we stand in relation to the "irreversible tipping point" for each. In the case of at least four – climate change, biodiversity, land-system change, and nitrogen and phosphorus imbalance – we are already operating in the high-risk zone.

Dramatic graphics showing Earth in flames or shattering like glass, and the advance of an implacable human army, seek to emphasise the sense of urgency. More compelling is the emotional testimony from scientists who have been left to document the decline for too long. *Breaking Boundaries* is a necessary bridge between scientific and mainstream understanding of an issue too often framed in terms of plastic straws.

It is more ambitious in its aims to educate than the average nature documentary, not only setting out the scope of the crisis, but drilling into the details. The 75-minute run time is densely packed, fast-paced

and – for those moved by facts as much as footage of struggling wildlife – undeniably dismal. By the time talk turns to solutions, the viewer will be left reeling at the scale of the challenge – but convinced of the necessity to act.

No doubt to encourage everyone's participation, it is still nonetheless disappointing that in the proposed path back to stability, equal weight is given to individuals' consumption (healthy eating, reducing waste) as it is to aggressive political action (halving emissions every decade). But the lasting impression is of urgency.

Disastrous trajectories have been reversed before, Rockström emphasises. Panic over the disappearing ozone layer in the 1980s spurred concerted political action that led to its recovery. "It was indeed fantastic to witness: scientists raised the alarm and the world acted," says Attenborough. This film sounds the alarm like never before. The question is, will we hear it? ■

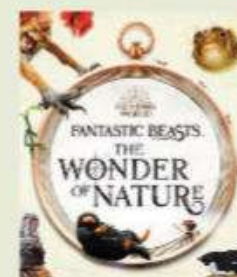
Elle Hunt is a journalist based in London



EDWARD FELTON

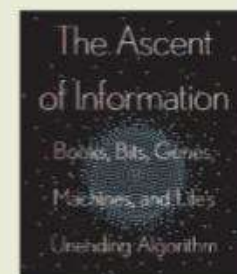
Breaking Boundaries aims to educate the viewer about climate change

Don't miss



Visit

Fantastic Beasts, both real and magical, stalk London's Natural History Museum until 3 January, revealing how mythical and imaginary creatures are inspired by real-life animals. With nods to all the connected films.



Read

The Ascent of Information, by astronomer Caleb Scharf, argues that data of all sorts is really an aggregated organism, controlling our behaviour and evolving alongside us. Terrifyingly, it has goals and needs.



Watch

Apples, directed by Christos Nikou, is a much-praised comedy-drama about a man developing a new identity after an amnesia pandemic. Available on demand from Curzon Home Cinema. See a full review on our website.

The film column

Looking glass worlds In *Parallel*, four friends find a portal to the multiverse. Will exploring it make them rich – or help one of them find his late father still alive? This familiar-ish premise depends on its sharp ideas for success, says **Simon Ings**



Simon Ings is a novelist and science writer. Follow him on Instagram at @simon_ings



SHANE HARVEY

Georgia King
plays failing artist
Leena in *Parallel*

intellectual property of unwitting inventors. No spoilers about the end result of all this, but it is a catastrophe worth waiting for.

Parallel is no masterpiece. Made on a shoestring, and boasting a silly and intrusive soundtrack, its fairly familiar premise depends on the sharpness of its ideas. Luckily, Blaszak knows what he is doing, and has given us characters who, while engaging enough, aren't good people. Handed a world of infinite possibility, all they can do is play out their failings.

They aren't even very curious. Bankrolled with money stolen from their "alt" selves, they consume, but they cannot create. Their cruelty is as devastating as it is casual. By bringing an alt Josh into our world, Noel destroys at least one innocent life. Then the alt Josh begins to mentally disintegrate, tormented by the tiny but ubiquitous differences between his world and ours.

Ezban's direction is efficient, more than inspired. Those wondering what he could achieve on a bigger budget might not have too long to wait. He has been hired by Sony Pictures to direct the adaptation of Dan Simmons's horror novel *Summer of Night*.

Meanwhile, *Parallel* is a well-constructed calling card. It is a film with heroes that are meant to be likeable, flawed as they are. Pulling its punches in this way gives the enterprise a curiously dated feel. I was reminded in particular of Joel Schumacher's *Flatliners* and *The Lost Boys*. Not every movie has to plummet the depths of despair, of course. But I do wish *Parallel*'s cast (Wallström in particular) had been handed more of an opportunity to chew up the set. ■



Film

Parallel

Isaac Ezban

DVD and VOD

Simon also recommends...

Book

The Man in the High Castle

Philip K. Dick

This alternate history traces the lives upended by intrigues between Imperial Japan and Nazi Germany, the post-war rulers of the southern and western United States.

Film

The Butterfly Effect

Eric Bress and

J. Mackye Gruber

Writer-directors Bress and Mackye Gruber (later of TV's Kyle XY fame) created a low-budget mind-bender, as Evan Treborn (Ashton Kutcher) travels through his memories to fix his past.

WHAT if you could step through a mirror and visit other versions of the world? Would you explore these alternate Earths? Would you try to find a better home for yourself – in a world, perhaps, where a loved one hasn't died?

Or, as happens in *Parallel*, Mexican director Isaac Ezban's first English-language thriller, would you simply go around stealing?

Of the four young friends who discover a dimensional portal in the attic of their rental, only Devin (Aml Ameen) thinks it might be a means of personal salvation. As a boy, he flew into a rage at his fraudster father, who killed himself the next day. Now Devin is in search of a version of the world where his father lives, and the rift can be healed.

His friends, however, simply want to get rich. The four have been working together on a parking app called Meter Maid: an idea so uninteresting, I wonder if it is meant as an early comment on their lack of real talent.

Behind their mirror, through which they pass, Alice-fashion, into other versions of the world,

time runs faster. For a moment, it seems that to get stupidly rich, all they have to do is bring back the winning lottery numbers from alternate realities. But the worlds they visit, though very similar, are different enough that the winning numbers don't match up.

Is there a way to exploit these little differences? Screenwriter

"Handed a world of infinite possibility, all the film's characters can do is play out their failings"

Scott Blaszak's first feature fizzles with incidental invention as the friends explore the commercial and financial angles of their multiverse. Their solutions are tailored to character. In the end, Josh (Mark O'Brien), the group lightweight, goes chasing women across the multiverse. Meanwhile, failing artist Leena (Georgia King) fills portfolios with plagiarised pictures and Noel (Martin Wallström, effectively reprising his role in *Mr Robot*) steals the

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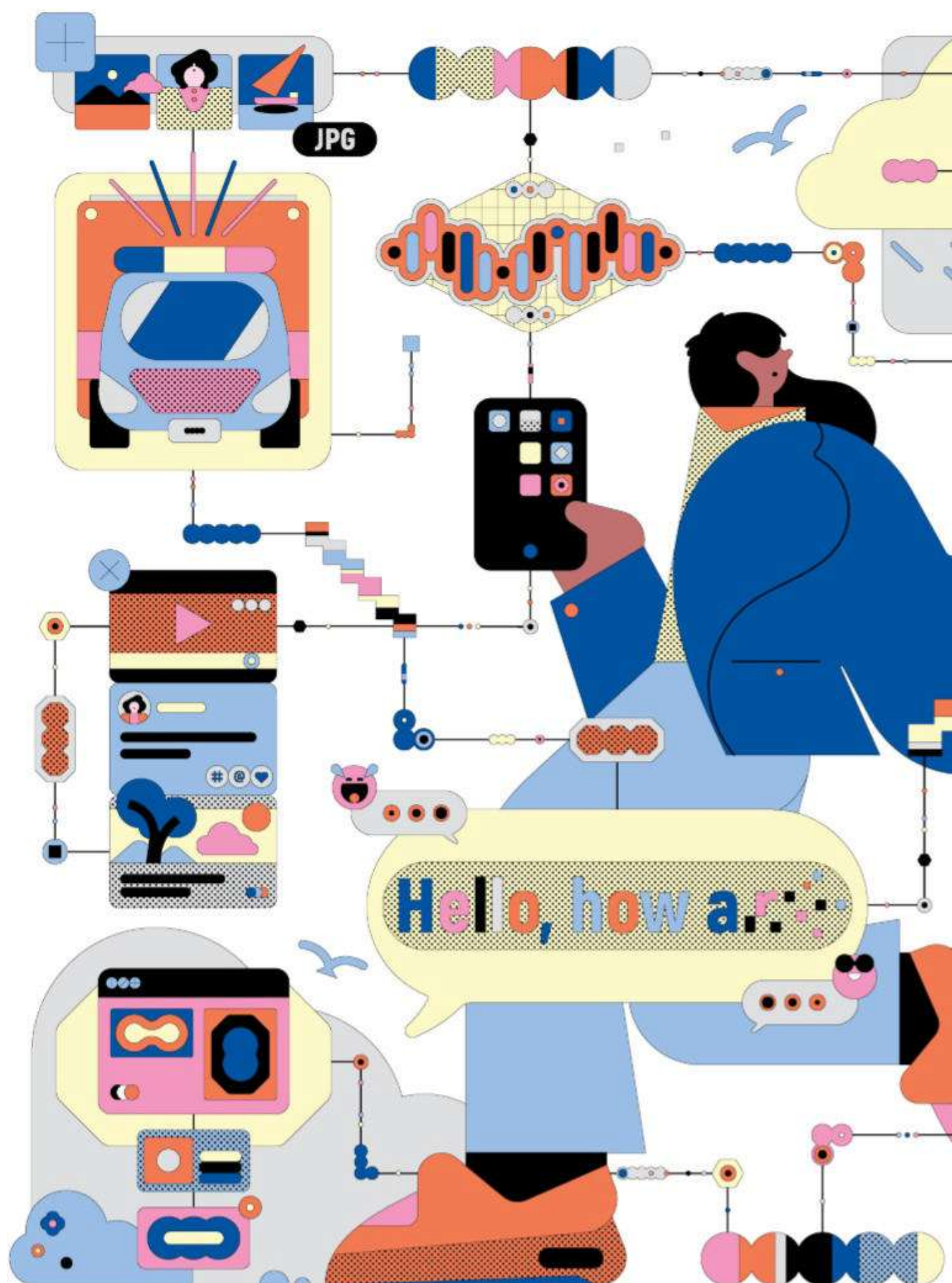
The algorithms that run your life

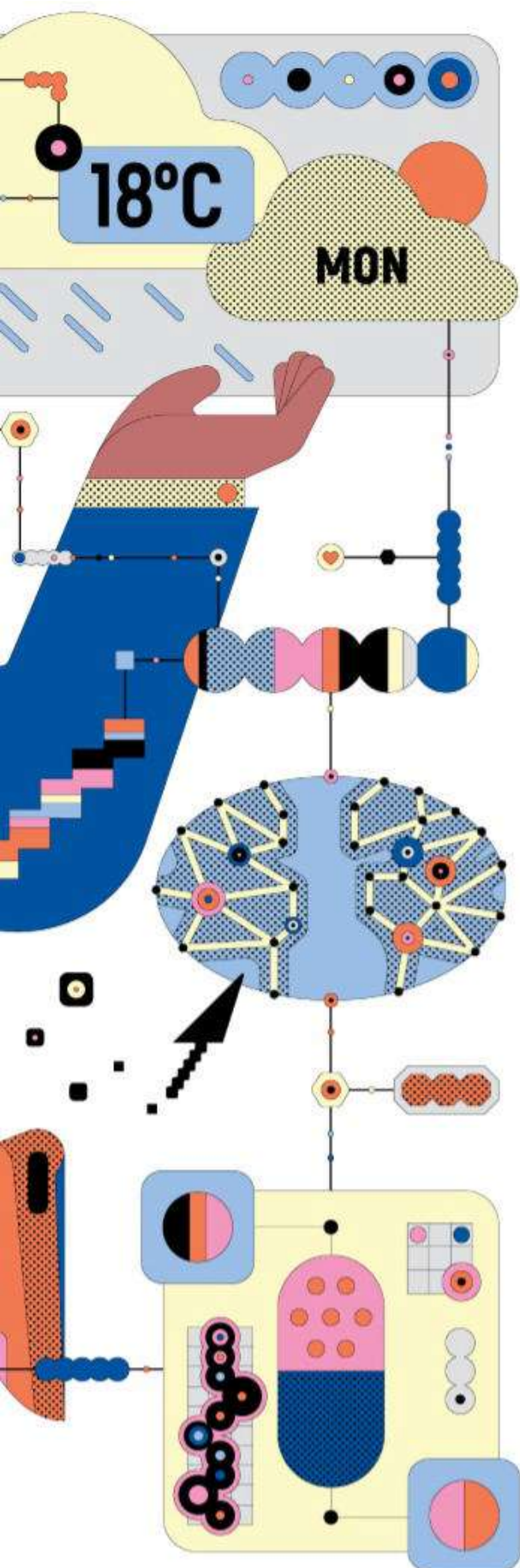
They shape our viewing habits, spot disease and keep our emails safe. Meet the algorithms that you rely on more than you might think

IT IS almost impossible to go a day without interacting with an algorithm. They help direct the whole of our online experience, recommending what we should buy, read, watch and listen to. Some 74 per cent of adults in the US use Facebook at least once a day – and what they see is decided entirely by an algorithm. Offline, they are increasingly used to help us make tricky decisions, screening job applications, moderating exam results and even directing which crimes police investigators focus on.

As they have become ubiquitous, algorithms have generated a mixture of hype and concern. On the one hand, we are regularly told that they can be opaque and biased. On the other, we hear that they can be incredibly handy, pulling off tasks that humans can struggle with, from optimising complex trade logistics to spotting the earliest signs of disease in medical scans.

So what's the truth about algorithms? It helps to understand that the word can mean quite different things (see "What is an algorithm?", page 36). It also helps to get to know some of the algorithms that shape our lives – so that's what we'll do over the next few pages.





BRATISLAV MILENKOVIC

1 SOCIAL MEDIA Facebook's news feed

Few algorithms wield as much power as those under the bonnet of Facebook. The social media giant's algorithms control which updates its 2.8 billion monthly users see from which friends and what headlines they read on their news feed.

When we speak of the "Facebook algorithm", we're actually referring to dozens of pieces of software that are based on a range of technologies and are constantly being tweaked. This software analyses what the firm calls the "inventory": the collection of posts from those people, pages or groups that a user follows. It then uses neural networks, a form of artificial intelligence, to score those posts on various factors. As far back as 2014, Facebook employees reported that the news feed was taking 100,000 factors into account. Eventually, it combines these scores into a single ranking for each post. This is used to curate what a user sees.

Facebook rarely talks publicly about exactly how its algorithms work. In truth, it doesn't know itself, at least not at the level of individual users. Nick Clegg, Facebook's vice president of global affairs, recently wrote that the results the algorithms produce are as unique to each user as their fingerprints.

This complexity could spell a reckoning for Facebook in the coming years. There has long been tension between the company's business model and what is perceived as good for society at large. Facebook wants to keep users on its site for longer so it can sell more ads. This has caused concern that its algorithms show people more posts about controversial topics, such as Brexit, because they tend to prompt higher engagement.

The company has long used human moderators to help decide whether controversial content should be removed or not. Recently, it set up the independent Oversight Board to review especially difficult cases. The board is composed of 20 journalists,

politicians, campaigners and academics, one of whom is technology law specialist Nicolas Suzor at Queensland University of Technology in Brisbane, Australia. "There are big problems to address, such as whether the way that news is amplified on social media aligns with our social aims," says Suzor. "These problems cannot be addressed until Facebook becomes more transparent about how the algorithms work." *Matthew Sparkes*

2 WEATHER FORECASTING The Unified Model

The British obsession with the weather may baffle the rest of the world, but one good thing to come of it is a first-class weather forecasting service. At the heart of the Met Office's forecasts is an algorithm called the Unified Model. It works by sucking in data on the state of the atmosphere from weather stations and satellites, then extrapolating to calculate how it will change. The results determine whether we see an icon for sunshine or snow.

The algorithm is built around the Navier-Stokes equations, our best description of how liquids and gases flow. These are how we predict the flow of dry and moist air in the atmosphere, a major factor in determining the weather. It isn't possible to solve the equations exactly, but you can do so approximately if you take a series of incremental changes in the state of the atmosphere and add them together. This is what the Unified Model does.

For decades, computer processors have been getting quicker, allowing algorithms like the Unified Model to process measurements made at ever shorter increments and so produce better, faster predictions. It can seem like weather forecasts get it wrong all too often, but the Met Office's next-day temperature ➤

What is an algorithm?

Ask a computer scientist this question and they will tell you it is a sequence of instructions that takes an input, performs some repeatable computation on it and provides an output. Think of an algorithm like a super-precise recipe, usually written in the cold logic of a programming language.

A simple example is the bubble sort, which arranges a list of numbers in ascending order. It begins by comparing the first two numbers. If the first is greater than the second, it swaps them. Otherwise, it moves on to the next pair. It cycles through the list again and again until it passes through without any swaps needed, at which point it outputs an ordered list. If you are shopping online and filter products by price, the bubble sort algorithm is kicking into gear behind the scenes.

These days, popular use of the word algorithm is morphing: it is increasingly used to describe almost anything that a computer accomplishes. That includes the realms of artificial intelligence (AI) and machine learning, where the steps in the recipe aren't always quite so clearly laid out.

Take neural networks, a type of AI system that mimics the human brain in that it can be trained to perform a task based on looking at examples of correct and incorrect results. Such "algorithms" can be incredibly powerful, but it is usually hard to look inside and determine how they really work.

There are those who find the loosening of the term algorithm to include AI unhelpful. "Now people use 'algorithm' to mean almost anything," says Martin Dyer at the University of Leeds, UK. "I've become so annoyed at people misusing it."

Dyer warns that, in future, we may increasingly lean on machine learning as an "easy way out" – a route to solve problems without fully understanding them ourselves.

He says we ought to apply the right kind of algorithm in the right context. There are times when a rigid set of predictable steps is desirable and times when highly capable but ambiguous AI can be beneficial. "It's fine if it gets wrong whether you like this book or not, but it's not fine if it crashes your car," says Dyer. **Matthew Sparkes**

School exams in England were moderated by algorithm in 2020, causing controversy



forecasts are accurate to within 2°C on 92 per cent of occasions. So, while it can't forecast every shower with total precision, it is a pretty reliable algorithm.

To get even better, the Unified Model is going to have to change. "We are no longer getting faster processors, we're just getting more processors," says Ben Shipway at the Met Office. He and his colleagues are now redesigning the model so it can be run on parallel processors. *Anna Demming*

3 DIGITAL SHARING JPEG

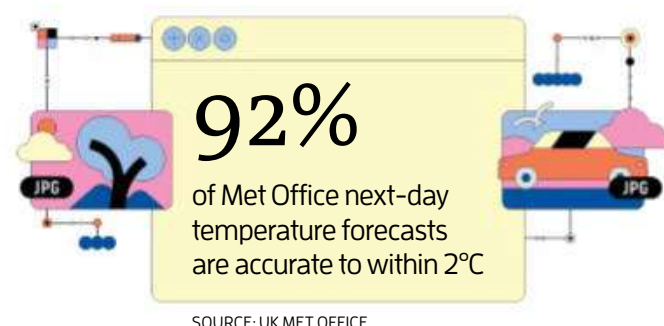
If you recognise the acronym JPEG, you might think of it as merely a type of file. In reality, it is an algorithm used to compress the amount of data in an image. The blistering speed with which we can share pictures online is partly thanks to compression algorithms like this one.

JPEG is named after the Joint Photographic Experts Group, which devised this standard back in 1992. The algorithm itself is quite sophisticated, but it is based on simple insights about human vision. "A lot of research has been put into what humans can perceive in images and sound, and it is a lot less than the files are capable of transmitting," says Jeff Waldock at Sheffield Hallam University in the UK. "So, for efficiency's sake, compression algorithms focus on what's important for an eye or ear to perceive."

Cone cells in the human eye, which register colour, are 500 to 1000 times less sensitive to light than the eye's rod cells, which are most sensitive to brightness. Among other things, JPEG exploits this by dropping some of the information about colour, while retaining the brightness more precisely.

There are situations where you wouldn't want to use a loss-inducing format like JPEG, such as in medical imaging or digital art. With compression algorithms, it is always a trade-off between quality and speed of transmission. Data speeds have increased drastically since 1992, but demand has skyrocketed too, so compression is still important. Other kinds of compression algorithms can squeeze down other types of file – MP3 is often used for music files, for instance.

There are plenty of would-be successors to JPEG designed for even more efficient data transmission. One of these is JPEG XL, which Jyrki Alakuijala at Google is working on. "Images are the heart of the internet," he says. "We are trying to introduce a new way to model colours." The idea is that this will produce images that are even better tuned to human vision. *Chelsea Whyte*

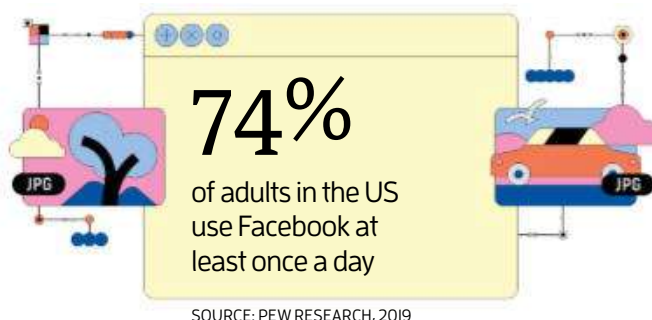


“We will surely be grappling with the legacy of PageRank for years to come”

4 WORLD WIDE WEB PageRank

Back in 1998, two entrepreneurs filed a patent for an algorithm called PageRank. They were Larry Page and Sergey Brin, the founders of a medium-sized internet search engine called Google. From there, Google quickly grew to be the clear leader in online search – and it was PageRank that made this happen.

Before Page and Brin filed that patent, search algorithms tended to rely on analysing the words on a web page. This determined which websites a user would be served when they entered a search query. PageRank worked differently: it assigned each link a rank based on the number and authority of any websites linking to it. If site A links to site B, site B will inherit some of A's PageRank, boosting its position on Google's results page. This turned the search market on its head, negating the tricks and workarounds that website owners were using to game the rankings. It provided



better, more accurate results.

The PageRank algorithm no longer has the influence it once did. Instead, Google now uses a series of different algorithms to analyse hundreds of different factors that decide where websites rank, drawing clues from all of Google's many products. You may not realise it, but your location, the time of day and the device you are searching from – plus many other subtle factors, not all of which Google reveals – affect your search results. As with so many other parts of the online experience, algorithms personalise what you see in a way that's hard to fully understand

(see “Facebook's news feed”, page 35).

It is difficult to overstate how much this algorithmic indexing has changed the world. Google's supremacy allows it to sell targeted advertising that nets it vast profits: \$46.2 billion of revenue in the third quarter of 2020 alone. But it has also sucked support from other industries, not least the media, which once enjoyed reliable streams of revenue from adverts. We will surely be grappling with the legacy of PageRank for years to come. *Alexander McNamara*

5 FINANCE Trading algorithms

Financial trading has always been an arena ripe for automation. It isn't just that humans frequently lose their nerve and make mistakes. There is also decades of price information ready to be analysed and used to develop rules on when to buy, when to hold and when to sell. Today, algorithms control a huge portion of the global economy.

“Good traders follow good rules, but as a human, you let emotions come in and you maybe panic or get too greedy,” says Nir Vulkan, a business economist at the University of Oxford. “Algorithms are the ultimate way to be systematic.”

One breed of finance algorithm carries out what is called high-frequency trading, where computers make vast numbers of trades at incredible speed. Each transaction is likely to generate only a tiny profit, but this adds up. These algorithms have been accused of causing financial crashes in the past. But they are only a small part of the market.

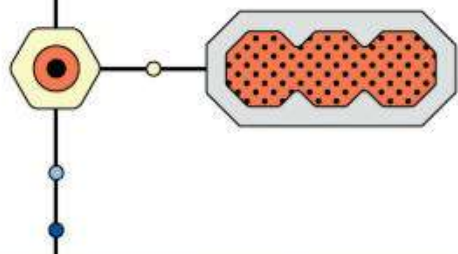
More common are algorithms that lay out the circumstances under which particular financial assets, such as shares and bonds, are bought and sold. It isn't so much about being quick, but about minimising human bias. Such digital rule books are mainly developed and used by funds handling huge pots of money and their inner workings aren't public. An increasing number of global financial



Stock market traders can make mistakes, so they built algorithms to make rational buy-and-sell decisions for them

SIMON BELCHER/ALAMY

“Many of the medicines we rely on wouldn’t exist without Monte Carlo algorithms”



Some algorithms can read medical images more accurately than human doctors

MARTIN BARRAUD/GETTY IMAGES

decisions are made according to these algorithms. “It’s growing all the time,” says Vulkan. “Hedge funds have secrets, so nobody can tell for sure, but I would guess it’s about half of the market now.”

We do know that trading algorithms are becoming more complex. Some funds are going beyond simple rules and using artificial intelligence and machine learning. Systems based on these can use not only stock market data as an input variable, but also things like the number of positive and negative words in a CEO’s media interview. In time, this might give firms with the smartest algorithms an advantage. *Leah Crane*

6

ENCRYPTION

The RSA algorithm

Ever used the internet? Then you have used RSA cryptography, a combination of algorithms and protocols that makes it possible to send information privately between computers. Those secrets could be anything from an email to your bank details.

Methods for sending secrets rely on scrambling the message in such a way that

only the intended recipient can unscramble it. A simple encryption method would be to move each letter in a message one along in the alphabet. You send “Ij!” and then the recipient knows to decrypt it by reversing the process to get the original “Hi!”.

Trouble is, the first time you send a message, you must overtly tell the recipient how to decrypt it, which weakens the system. But here is a cunning trick: if you use an encryption key that comes in two parts, one public and one private, you can encrypt your message with the recipient’s public key but they alone can decrypt it with their private key.

The way to pull this off is to have a process that is easy to do in one direction (encrypting the message), but hard to do in the other (decrypting the message). The RSA algorithm

does this with a quirk of prime numbers. Multiplying primes together is simple, but factorising the number produced to get back the original primes takes a lot more time.

In real life, the RSA algorithm deals in truly gigantic primes and the system is practically impossible to break – for now, at least. Factorising numbers into primes is only hard for classical computers. For a big enough quantum computer, it will be a breeze. But fear not – work is under way on cryptography that relies on other, more quantum-resistant mathematics. *Timothy Revell*

7

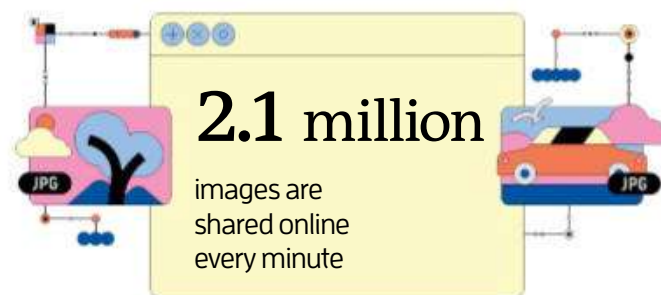
HEALTH

Triage algorithms

Imagine you start feeling a crushing chest pain. You quickly phone the emergency services for help. In many countries, it will be an algorithm on the end of the line – well, sort of. The call handler will take you through a series of questions governed by an algorithm to work out if you are having a heart attack or something else. The outcome determines if an ambulance needs to be sent and how quickly. “If you put everything as a priority, then nothing is a priority,” says Richard Webber at the UK’s College of Paramedics.

Elsewhere in medicine, algorithms are beginning to be used without much, if any, human intervention. In the online version of NHS 111, the UK’s non-emergency healthcare triage service, users are taken through a series of completely automated questions to help direct them. There are also several “symptom checker” apps available. These ask about your medical problems and then, based on an algorithm, suggest a probable diagnosis. However, the UK’s Royal College of General Practitioners has said that such apps can’t yet replace doctors’ abilities to make decisions based on their breadth of experience, their training and, sometimes, their gut instincts.

More sophisticated machine-learning algorithms are being used too. There are several systems that can read medical images,



SOURCE: STATISTICA, 2019

spotting signs of a broken bone in an X-ray, for instance, or the onset of diabetes-related blindness in an eye scan. Algorithms like this are developed by training the software on thousands of images that have been categorised by doctors. In some cases, these systems have outperformed trained professionals and some hospitals are already using them, usually double-checked by a doctor, to help make diagnoses far more quickly. *Clare Wilson*

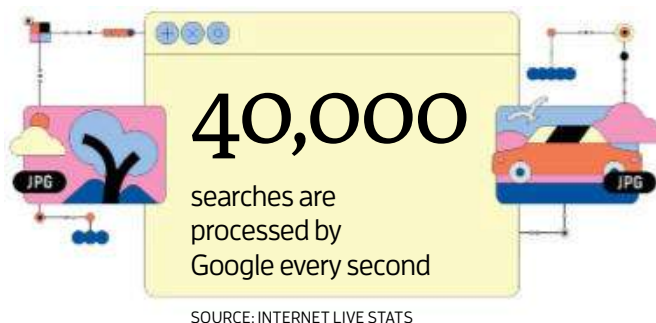
8 INTERNET The internet protocol suite

When you fire off an email or type into a browser, you are asking your computer to exchange messages with another one somewhere in the vast digital expanse of the internet. This miraculous connection is governed by a sprawling set of algorithms and rules known as the internet protocol suite.

The purpose of these rules is to make sure traffic gets where it needs to go. To that end, the algorithms don't specify exact routes through the cables that make up the internet in case parts of it get disrupted. Instead, the message is chopped into packets and the algorithms help them find a way by any viable route, with each packet basing its trajectory on feedback from the one in front. Once at the destination, the packets are put back together.

This algorithmic rule book was written by computer scientists Vint Cerf and Robert Kahn and implemented in 1974. It has formed the backbone of the internet ever since – but it has needed a few tweaks along the way.

One reason for this is that it works hand-in-glove with the internal protocol (IP) address system, which gives each connected device, from servers to smartphones, a unique, machine-readable identifier. As the world became ever more connected, the number of available IP addresses dwindled, and in 2017 we all but ran out. This was because IP version 4, the first publicly used version of the internet, was structured such that



only 4.3 billion IP addresses were available.

Thankfully, the internet got an upgrade. The new address system, IPv6, has more possible addresses than there are atoms on the surface of Earth. So, even with trillions of future devices to be connected to the internet, we won't run out of addresses any time soon. *Donna Lu*



One of the most important algorithms in science was first tested on a card game

9 SCIENCE Monte Carlo algorithms

The scientists developing the atomic bomb during the second world war needed to understand nuclear chain reactions – and there was no room for error. The problem was, the physics was far too complex to analyse with conventional methods. So mathematician Stanisław Ulam devised a set of algorithms that could solve the problem in a new way, harnessing the nascent computers of the time.

The idea was to fake the physics many times over and see what tended to happen on average, producing not a direct answer but the most probable outcomes. Ulam named the algorithm after the card game Monte Carlo – sometimes called solitaire – because he first tested it by modelling outcomes of the game.

These days, Monte Carlo algorithms are employed incredibly widely, from forecasting stock market trends to the output of wind farms. “They are important because they can be used to understand complex situations where there is no analytical formula that would allow one to directly compute the result,” says computer scientist John Guttag at the Massachusetts Institute of Technology.

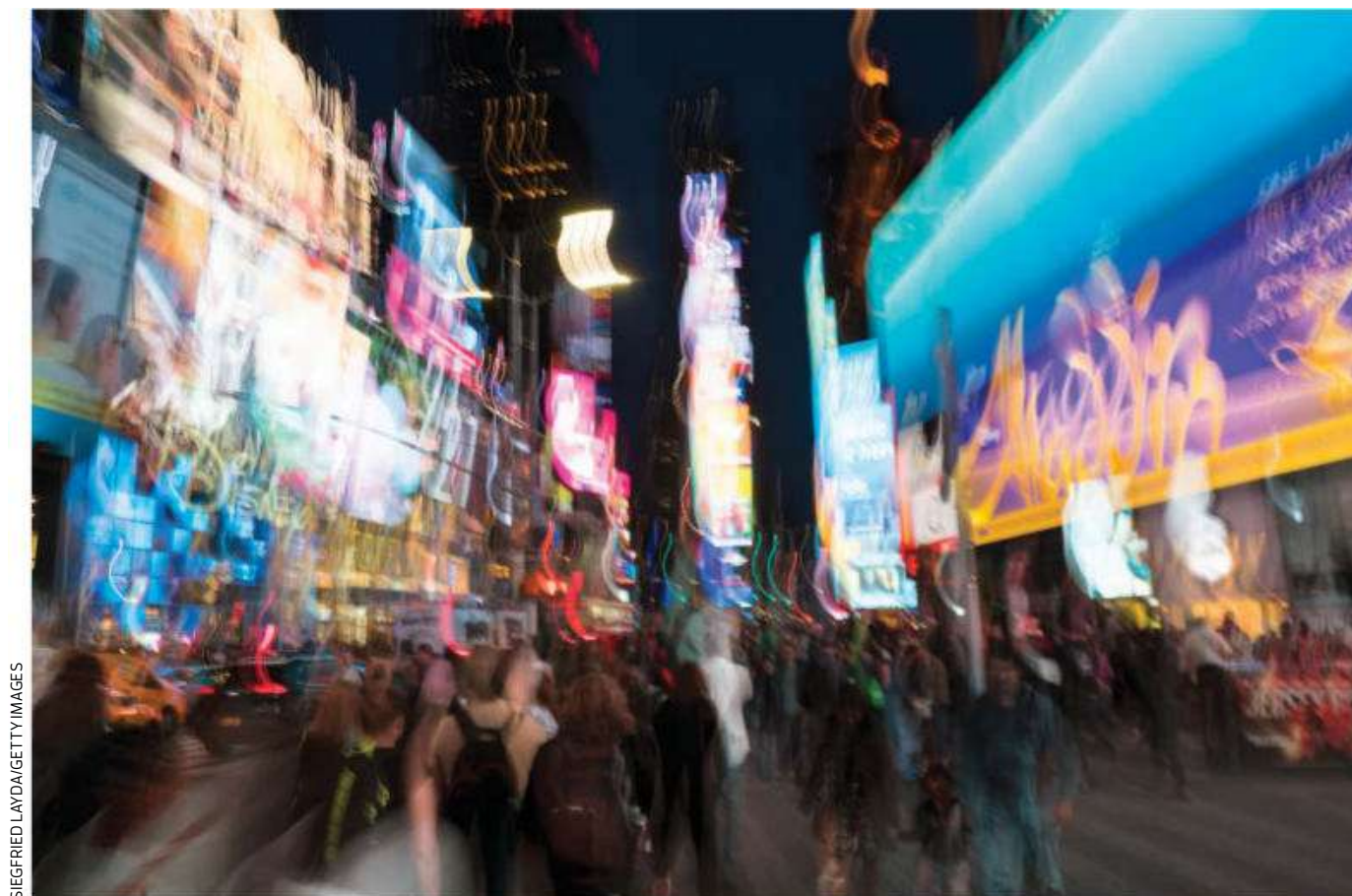
They are especially useful for scientists wrestling with complex phenomena. For instance, they are routinely used to figure out what shapes of molecule can best glom on to important proteins, providing a lead on compounds that may be useful drugs. Many of the medicines we rely on wouldn't exist without Monte Carlo algorithms.

We are still finding new uses for them. One devilish problem in physics is understanding the behaviour of materials in which lots of electrons whizz around and mutually affect each other. The maths is nigh-on impossible, which means we can't predict how materials we haven't yet made will behave. Roger Melko at the Perimeter Institute in Waterloo, Canada, has found a shortcut. He uses Monte Carlo algorithms to do the work instead, applying them to hunt exotic new states of matter. *Daniel Cossins* ■

"Institutions are designed to create the illusion of consensus. They aren't looking for the correct answer"



Behavioural scientists Daniel Kahneman and Olivier Sibony tell **Graham Lawton** why "noise" in judgements gets in the way of truth and fairness across society



SIEGFRIED LAYDA/GETTY IMAGES

IF YOU have ever jumped to the wrong conclusion, made a terrible mistake thanks to your inbuilt biases or been subtly nudged back to your senses, then you are (a) human and (b) already on personal terms with the work of Daniel Kahneman, Olivier Sibony and Cass Sunstein. Thanks to their academic and popular writing, the world is now very familiar with what are collectively called “cognitive biases” – systematic errors in human thinking – and ways to correct them.

Sunstein co-wrote the highly influential book *Nudge: Improving decisions about health, wealth and happiness* with Richard Thaler, while Kahneman popularised the work that won him the Nobel prize in economics in 2002 with his book *Thinking, Fast and Slow*. Sibony is the author of *You're About to Make a Terrible Mistake: How biases distort decision-making and what you can do to fight them*.

You may think that, in no small part thanks to their efforts, the swamp of human fallibility has been well and truly drained by now. But that would be yet another mistake. Kahneman, Sibony and Sunstein say there is an even more important source of warped decision-making. The three have banded together in a

behavioural science supergroup to draw attention to what they call “noise” – persistent inconsistencies in professional judgements that lead to bad outcomes in all walks of life.

Kahneman and Sibony spoke to *New Scientist* about the group's new book *Noise: A flaw in human judgment* (Little, Brown Spark in the UK; William Collins in the US). Sunstein was due to join the conversation, but was called away at the last minute by his new boss, US president Joe Biden.

Graham Lawton: We are familiar with the idea that human decision-making is bedevilled by cognitive biases. Your book is about a different source of error, noise. Can you explain the difference?

Daniel Kahneman: Noise is the amount of disagreement between people who make professional judgements. Think of an organisation, like a medical system or a justice system, which has individuals who perform judgement tasks. Noise is the variability of their judgements on the same task.

The existence of noise is obvious to everybody: judgement tasks are defined by the fact that reasonable people can disagree,

otherwise we don't call it judgement. But it turns out there is more noise than people expect. Much more.

Olivier Sibony: One of the mottos of the book is wherever there is judgement, there is noise. And more of it than you think.

You list many areas where noisy judgement is a problem, from criminal justice to medical diagnosis to hiring and firing. But these are just the tip of the iceberg. Can you give some specific examples?

DK: Some years ago, I was consulting in an insurance company, and I proposed to run a study of noise in the judgements of their underwriters. So they constructed cases – very naturalistic cases from their point of view – and presented them to about 50 underwriters. They were shown one or more of these cases and made judgements.

I asked a few executives about their expectations. Suppose you take two underwriters at random, and compute the difference between their judgements in percentages. What percentage do you expect to find on average?

The answer was 10 per cent, which turns ➤

out to be a very general answer. Olivier has surveyed hundreds of people, and the most common answer is 10 per cent. But what we found for underwriters was 55 per cent. That is a big difference. It is, in fact, so large that it raises questions about the need for people to make that judgement.

This was unknown to the company. It came as news to them that they had a noise problem. So that's how it began.

I must admit, when I first read the word "underwriters" in your book, I misread it as "undertakers", which made me laugh.

OS: We hope there is not too much noise there! Anyway, this process is what we now call a noise audit. And we went through the literature, looking for examples of studies in which people had done noise audits – without, of course, calling them that. We found a lot.

One striking example is the US judiciary. Years ago, a study was done of the sentencing decisions of 208 federal judges. Again, the difference was in the region of 50 per cent of the mean. So, if you pick two judges at random and you give them a case that has a seven-year average prison sentence, the difference between them is in the region of three-and-a-half years.

That is staggering. The mere fact that the lottery that assigns judges has assigned you Judge X rather than Judge Y means the difference between five years in prison or nine years in prison.

That is serious. Why have we paid such little attention to noise until now?

DK: Noise is difficult to think about. The human mind seems to be specialised for thinking about particular cases, and for thinking causally. It seems to have significant difficulties thinking statistically about ensembles of cases.

What is striking is that when you think about a single case, you can identify bias, but you will never identify noise. No single case appears to be noisy. That is one important reason why noise is so neglected.

Another is something called naïve realism. In general, when we look at the world and make judgements about it, we feel we're getting it right. We see the world as it is. And if you're sitting next to me looking at the same world, and I respect your judgement, then I fully

expect you to see the world exactly as I do. But probably you don't.

OS: There is a third reason. You have to ask: why don't organisations realise this problem? Why doesn't the insurance company realise it? Why doesn't the judicial system become aware of so much variability? Why don't hospitals become aware of the fact that doctors have, quite often, very different diagnoses of the same patient? You would think it's in their interest.

We think part of the answer is that organisations are designed to suppress evidence of noise. They're designed to sweep the problem under the rug and to create the illusion of consensus. They are not looking for the correct answer. One way to do that is never ask people for their opinions separately. You bring them into a meeting and you ask them to discuss it. Which, of course, gives a strong incentive to the second speaker to agree with the first one, and the third person to agree with the first two, and so on.

One psychologist we interviewed told us that he was working with the admissions department of a university. He advised them that it would be a good thing, when two admissions officers grade an essay, for them to grade it separately and then to discuss their differences. And the answer of the university was "oh, that's how we used to do it, but we disagreed so much that we adopted the current system, in which the second evaluator sees what the first one has done".

DK: Many professional judgements receive no feedback. You make a judgement and you never know how accurate you are. This is

"A lot of professional judgement actually has no connection with reality"



certainly true for judges and underwriters. It's true even for radiologists, who make a diagnosis but very rarely hear what the autopsies say.

So, a lot of professional judgement actually has no connection with reality. And this allows different professionals to diverge from each other without knowing that they are diverging. In the absence of feedback, you have experts. We call them "respect experts" because they're respected by their colleagues, and what they say has a sense of being true, although there is no objective way of measuring that. That certainly helps obscure the role of noise.

No wonder people are sick of experts. What about science? At least it has peer review.

DK: There are quite a few studies of judgement in science, specifically the judgements scientists pass on each other's work.

The amount of noise is embarrassing. There may be agreement among scientists about objective facts, but when it comes to evaluating an article or a grant, it turns out that scientists disagree as much as other professionals do – again, because there is no obvious objective criterion for the quality of an article. It is a subjective judgement. And where there is subjective judgement, there tends to be a lot of noise.



A judge's life experience – and mood on the day – can impact their decision-making

The book is concerned with professional judgements, but does it also apply to everyday decisions?

OS: To the extent that you want those judgements to be accurate, it does. Now, what judgements in your daily life do you want to be accurate? Do you want to make an accurate judgement when you get married? Personally, I wouldn't think about it that way. I think you're making judgements of a different type.

On the other hand, if you are trying to decide whether you're buying your house at the right price, or whether the job you are going to take is the right job, these are judgements that lend themselves quite well to the type of approach that we talk about, because they're quite close to being professional judgements.

What are the psychological sources of noise?

DK: There is a fair amount of psychology to explain it. In *Thinking, Fast and Slow*, the attempt was to characterise the human mind in general. Here, the main aspect we're interested in is individual differences, different people making different judgements. So it's a different cut through the psychological cake. Where the psychology becomes interesting, I think, is in the distinction that we draw between different types of noise. We identify three sources of noise.

OS: The easiest way to describe them is to think of the example of facing a judge. You are going to be sentenced, and you are going to be assigned to one judge or another. You're assigned to Judge X, and your lawyer says "oh, thank God, it could have been Judge Y! Judge Y is a real hanging judge. You got lucky. Judge X is much nicer." That's what we call level noise – different individuals have different average levels in their judgement.

The second thing is that each of us has within-person variability. So Judge X could, in fact, be in a foul mood today. This morning, he happens to be worse than Judge Y. So, there's variability within each judge. That's what we call occasion noise. The occasion matters. We're all aware that there are decisions we are making today that we wouldn't have made on another day.

For a long time, we thought that was it, but eventually it dawned on us that there is a third type of noise, which turns out to be the largest. It's a little harder to wrap your mind around. So, if you give two judges 10 different people to sentence, and you ask them to rank these 10 cases from the most punishable to the least, they will not have the same ranking. Their fundamental beliefs are different. Essentially, they have different tastes.

That's what we call pattern noise. And this

source of difference between individual judges – in the broader sense, not just the judicial one – is the most important source. People are different. They have different backgrounds, different histories, different preferences. They've learned different things; they have failed to learn other different things. Therefore, we can't expect them to be identical.

You mention diagnosis. You would think that two doctors looking at the same case ought to be able to arrive at the same objectively correct diagnosis, but they don't.

DK: It is actually surprising and depressing the extent to which there is noise in medicine. The worst case is psychiatry. But there is a lot of variability in diagnosis of tuberculosis, for example.

Some of it is occasion noise. If one physician has seen two cases of a particular disease in the past few days, he or she is primed to see more cases of that disease than somebody who has not. In other judgements, it's the other way around. If a banker has approved two loans, the banker is less likely to approve the next loan.

Physicians could also have different ways of looking at cases, like different orders in which they consider diagnoses. If a diagnosis comes to mind more easily for one physician than for another, he or she will be more likely to make that diagnosis. And that's only one other difference.

While we are on doctors, they have embraced technologies like artificial intelligence to help them make better diagnoses. Is that the answer?

OS: Yes and no. It's a way out for tasks in which there is an objective truth. Is this tumour cancerous or not?

Where we have sufficient data to train algorithms, it's pretty clear that these tasks of judgement will stop being tasks of judgement. They will become automated tasks. A lot of things that are done by algorithms today used to be matters of judgement.

Deciding whether you got a small consumer loan used to be a matter of judgement. You had an interview with the banker at your local bank. Now there is an algorithm that makes that determination, and we all think that's fine.

A lot of simple judgements like that will be automated. Our focus, though, is not on ➤



Physicians may be primed to see a particular diagnosis based on recent cases

those. Our focus is on the very large number of judgements that – either because they cannot be automated or because we don't want them to be automated – are going to be matters of judgement for a long time. And we try to give people who make those judgements tools to make them less noisy.

What kind of tools?

OS: One of our first calls to action is for people to do more noise audits to start measuring this problem in their organisations so that they can decide whether it's worth addressing. We think, in many cases, their answer will be yes.

Once an organisation sees its noisy decision-making, what can be done?

DK: The first step is to get a good collection of options. On that, we have nothing to say. But if there is a good collection of options, there is a disciplined way of comparing the options, and we recommend that way of proceeding.

OS: We call it decision hygiene – list all the options, decide how to evaluate them, make those assessments separately and then come to a conclusion.

You admit that decision hygiene is as unglamorous as it sounds. Can you glamorise it a bit?

DK: It goes back to the distinction between bias and noise. If you propose a technique to overcome a bias, that will be the equivalent of medication or vaccination for a known disease. Decision hygiene is a bit like washing your hands. You have no idea what germs you are killing, and if you are successful, you'll never know. The procedures are preventive. You want to apply them when you're not

specifically aiming to prevent any particular bias, just to bring some uniformity and some discipline to judgement.

Is there any risk to eliminating noise? Are there not some benefits to having different outcomes when different people evaluate the same information?

DK: As we define it, there is no good noise, because we define noise as variability in judgements that should be identical. Variability can be very useful. In fact, it's essential when there is feedback and selection. But in the absence of feedback and selection, variability is just a source of error.

OS: There are situations where reducing noise is not worth it. There's a cost-benefit analysis to be done where the answer might be that tolerating some noise is just fine because it's not very consequential. We think those cases, though, are much less frequent than the cases where noise is large and problematic.

"Decision hygiene is like washing your hands. If it works, you'll never know what germs you are killing"

Do the ideas and actions in the book have any relevance to huge societal challenges like, say, pandemic responses?

OS: The pandemic is a really interesting case because, usually, when there is a big crisis like this, you see a singular decision. But here you see all countries responding to what is essentially the same problem with differences in timing and scope and so on.

A striking example was the Oxford/AstraZeneca vaccine side effects, and each health agency in each European country coming to a different conclusion about what to do – some saying let's ban it altogether, some saying let's keep it altogether, some saying let's ban it for people under a certain age, some saying let's ban it for people over a certain age. Looking at the same evidence with supposedly the same set of objectives, very smart and highly qualified people came to very different conclusions. We think if they had more disciplined thinking, we would see less noise.

You have spent years working against bad decision-making, discovering its causes and developing ways to do better. Yet the same types of bad decisions are made again and again. Are you fighting a losing battle against human fallibility?

DK: I wouldn't say that things are completely unchanging. I think there is more systematic use of intelligence in decisions than there was before. There has been progress. But it is slow.

OS: The time it takes for ideas to get into the organisations that can actually do something with them is quite long. One of the things that books like this can hope to accomplish is to actually shorten that time.

But the beauty of noise is that you don't need to understand the causes of bad judgements in order to fix them. That makes it a lot easier to combat because you don't have to point your finger at anybody and say "hey, you are biased". You can say "our system is noisy, let's make it more disciplined". I think that's a very liberating thought. ■



Graham Lawton is staff writer at New Scientist and author of *The Origin of (Almost) Everything*. Follow him @GrahamLawton

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Earth's past on ice

Glaciers contain precious clues about the planet's environmental history. Scientists are scrambling to capture them before they melt away, finds **James Dacey**



RICCARDO SELVATICO

MARGIT SCHWIKOWSKI and her team were attempting to drill into the Corbassière glacier in the Swiss Alps when the weather started to turn. They were camped among the soaring peaks of the Grand Combin massif. The only way off this vast sheet of ice in a storm is to descend a steep mountain wall or traverse the jagged glacier surface itself, which claims several lives a year. Instead, they retreated by helicopter before it was too late.

For Schwikowski, an environmental chemist at the Paul Scherrer Institute in Villigen, Switzerland, the risks of missions like this October 2020 expedition to Corbassière are worth it. The team she was leading is part of an international enterprise that aims to preserve the “memories” frozen into mountain glaciers across the world, by drilling out long samples all the way from the young surface snow down to the old, compacted ice at the base of a glacier.

These ice cores are loaded with information about Earth’s past that could be crucial in our fight against global warming. Locked within them is a picture of how the planet’s climate has changed over time, as well as evidence of human activity as far back as the Romans, clues about the evolution of microorganisms and much more. Now, scientists are racing rising temperatures to rescue ice cores from the world’s glaciers before they melt.

Mountain glaciers, also known as alpine glaciers, are slow-flowing rivers of ice. They begin life at high altitudes where the amount of snow settling in winter significantly exceeds the amount that melts in the summer. Over time, the snowpack builds up and the overlying weight causes snowflakes in the deeper layers to gradually transform into blue-tinted glacier ice, which eventually creeps downhill under its own weight.

“Deep within glaciers there is an amazing process, where ancient air is preserved from the time when it became trapped in the ice,” says Schwikowski, describing an effect of the increasing density with depth. This critical depth where not even air can escape is around 45 metres in the European Alps (see “What a glacier remembers”, page 48). The trapped air is just one relic that will be lost forever if sample ice cores aren’t gathered before the glaciers melt. Schwikowski and her team are rushing to extract samples from the planet’s most vulnerable glaciers. “There are not so many groups in the world who can do this ice-core drilling and so we have to focus our forces.”

Sadly, in the case of the Corbassière glacier it is already too late. Even before the weather turned, the mission was scuppered. At each attempt to extract an ice core, the scientists hit a hard layer known as an ice lens. These form when glacier surface layers melt, causing water to percolate through the snow, before refreezing into a thick ice sheet below. With the chronology of ice layers mixed up like this, valuable scientific information is lost forever.

The glacier appeared to be in good shape during a test run in 2018, but two exceptionally warm summers must have taken their toll. “The way this ice archive was damaged so extensively within just two years tells you how sensitive these glaciers are,” says Schwikowski.

It is a similar story across the world. Glaciers are shrinking at alarming rates. More than 9 trillion tonnes of glacier ice was lost between 1961 and 2016, adding 27 millimetres to the average global sea level, according to a 2019 study led by Michael Zemp, director of the World Glacier Monitoring Service. That corresponds to an ice block the size of the

UK with an average thickness of 44 metres, he says. If current melting rates continue, glaciers will vanish entirely from Europe, New Zealand and the west of North America, among other parts of the world, by the end of the century.

The result will be a further rise in sea levels globally, with all the knock-on effects for people, especially those living near coasts and in rural communities that rely on water from seasonal ice melt. For scientists like Schwikowski, the melting of the glaciers also endangers an unparalleled archive in the ice of Earth’s environmental past, prompting the launch of the Ice Memory project in 2015. Now backed by UNESCO, the United Nations Educational, Scientific and Cultural Organization, this international effort brings together researchers from various fields. “We had to take action before it is too late. These archives are formidable records of our past and they must be preserved for future generations of scientists,” says Carlo Barbante, a chemist at the University of Venice, Italy, and a co-founder of the project.

Geologically speaking, mountain glaciers hold a fairly young ice record, typically spanning the past 1000 to 10,000 years. One thing they can’t do is build a picture of the really long-term climate. For this, scientists mostly rely on older ice samples from continental ice sheets in Antarctica and Greenland. These are also threatened by global warming, but their shrinkage will occur over thousands of years, so they are beyond the scope of the Ice Memory project.

Although younger, mountain glaciers have one major advantage over the ice sheets – their geographical spread. They exist on all continents except Australia. This helps us to build a truly global picture of relatively recent past climates and means the information they contain is also highly region-specific.

Since ice-core projects investigating European glaciers began in the 1970s, they have identified a range of clues to conditions at various times, from local biological matter to Saharan sand and volcanic dust blown by the wind. These glaciers also tend to be close enough to human activities to carry a record of our impact, too. Nitrogen oxides from cars, heavy metals from industry and radioactive pollutants from the 1986 Chernobyl disaster have all left their mark in the ice. Studies have even found lead and antimony linked to the production and use of pipes and silver coins by the Romans.



Left: A drilling site on the Corbassière glacier, Switzerland. Above: an Ice Memory project scientist lowering a drill, and holding an ice core

That's all important, but understanding past climates is the real draw when it comes to ice cores from mountain glaciers. Information is encoded in the different types of water at different depths in the ice. During warmer periods, larger quantities of heavier forms of water – where the hydrogen and oxygen atoms in the water molecules have more than the usual number of neutrons – evaporate from the oceans. Some of this heavier water ends up falling back to Earth as snow on glaciers, providing a nifty way of reconstructing past temperatures.

Frozen life

It may even be possible to unpick some of the impact of past changes in climate on ecosystems. One way to do that is through the microorganisms stored inside mountain glaciers. Traditionally, investigations of ice-dwelling microbes involved growing them from field samples, which favoured certain “lab-happy” microorganisms. However, genetic sequencing technologies are bypassing this requirement, enabling biologists to gain a more complete picture of glacial ecosystems directly from the field samples themselves.

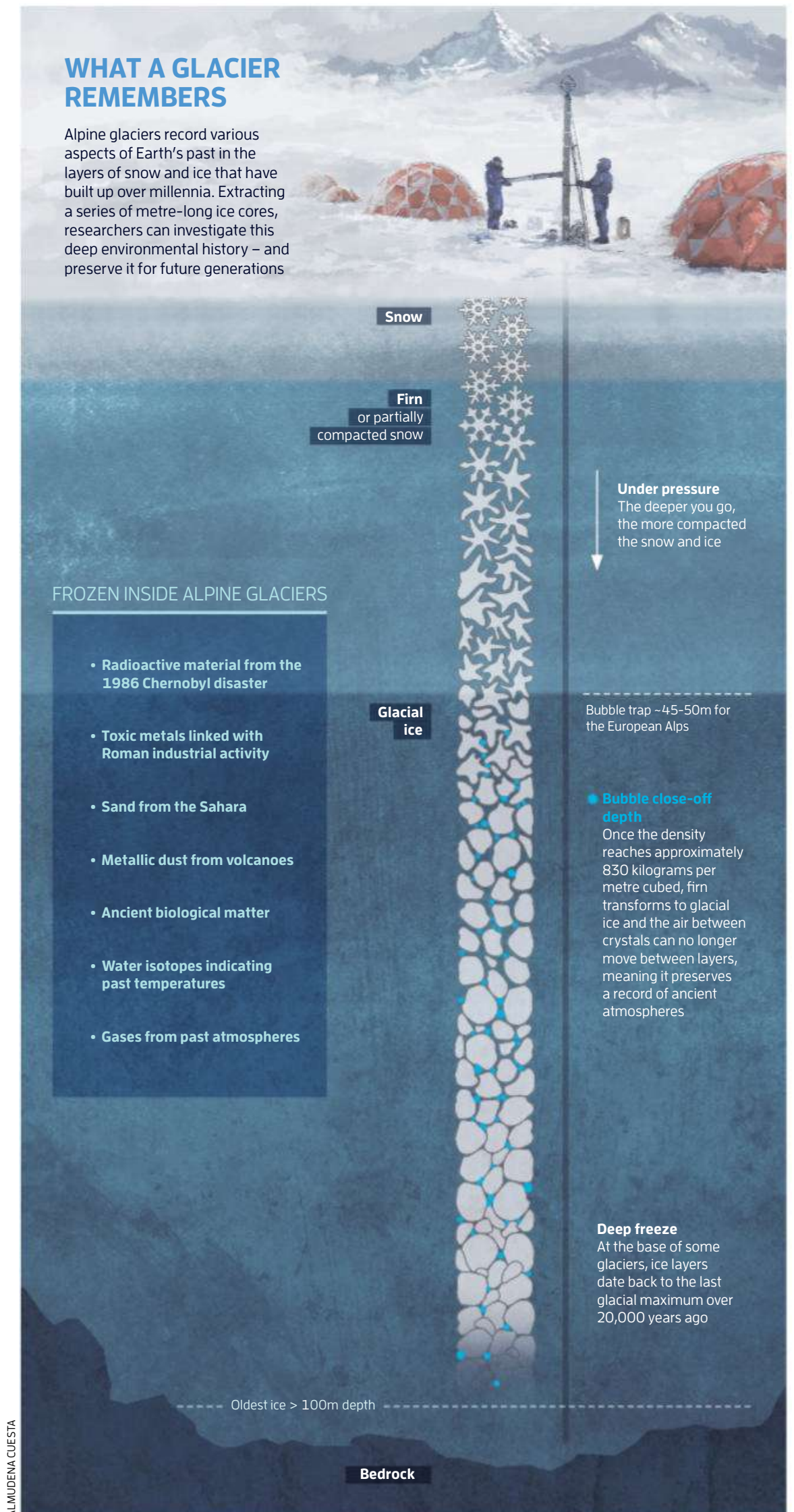
“There are so many questions we can start to ask,” says Catherine Larose, a microbiologist at École Centrale de Lyon in France. “If you have these ancient ice cores, can you find very old forms of life? Are things that existed in the past similar to what we see now?” One line of this research is to build a picture of an ecosystem by tracking how microorganisms and their genes have evolved in response to environmental pressures. For instance, an abundance of genes linked with mercury resistance would imply the presence of this highly toxic element, whose natural sources include volcanoes and forest fires.

Eager not to miss out on these clues to the past, researchers involved with the Ice Memory project have fanned out across the world to gather samples. In 2016, the launch mission extracted three ice cores from the Col du Dôme glacier at an altitude of 4300 metres on Mont Blanc in France. Since then, cores have been extracted in 2017 from the Illimani glacier in Bolivia – where glaciers hold records dating back 18,000 years – and from two sites in Russia during 2018. The plan is to extract cores from a further 20 sites across the world over the next 10 to 15 years.

The scientists drill near the highest points of glaciers, where snow and ice accumulates, rather than lower down the glacier tongue, where downhill flow mixes the ice record.

WHAT A GLACIER REMEMBERS

Alpine glaciers record various aspects of Earth's past in the layers of snow and ice that have built up over millennia. Extracting a series of metre-long ice cores, researchers can investigate this deep environmental history – and preserve it for future generations



But nature doesn't always play ball. Patrick Ginot at the Institute of Environmental Geosciences (IGE) in Grenoble, France, who led the Bolivia mission, recalls battering winds and heavy snowfall for two weeks at 6300 metres above sea level. "There were days on the summit of Illimani when we could not work at all."

Poor weather last month also led to Ice Memory researchers postponing a May mission to the Colle Gnifetti glacier on the Monta Rosa massif on the Italian-Swiss border until June, when they extracted cores down to the bedrock. At 4500 metres, Colle Gnifetti's accumulation zone is the highest in Europe, with ice dating back 15,000 years. "Besides a long climate record, the site also contains information about human history, for example changes in land use and crop cultivation or pre-industrial mining activities," says Schwikowski.

Beyond Europe, the next target is Mount Kilimanjaro in Tanzania, where you can find the only glacier left in Africa with enough ice to be useful for climate studies. At an altitude of almost 6000 metres, the ice on Kibo, Kilimanjaro's highest peak, provides a unique opportunity to study the past composition of the tropical middle troposphere – an important region of the atmosphere for global weather and climate processes. But the clock is ticking, as roughly 85 per cent of Kilimanjaro's icy cap has melted over the past century.

The long view

Battling the elements isn't the only challenge for these expeditions, there are logistical hurdles to navigate, too. The scientists need permits from governments, local assistance with transport and a reliable refrigeration chain to ensure that samples don't melt. These local partnerships are an essential element of Ice Memory. Project scientists are acutely aware of the damage that could be done by European scientists "parachuting in" to less scientifically developed nations to extract samples for the benefit of their careers. "Our way is always to start by building a collaboration with local scientists and then to organise the operation from there," says Ginot.

Even after all this, retrieving the ice cores is only half the battle, as they also need to be stored. The plan is to house them in a purpose-built "ice sanctuary" facility at the French-Italian Concordia Research Station, more than 1000 kilometres inland from the south-east coast of Antarctica. The location was chosen for being politically neutral and reliably cold over the long term, so there is no threat of freezer

failure wiping out millennia of data. There, cores will be kept in ice caves, created by inflating a sausage-shaped balloon covered in snow in a process reminiscent of papier mâché. The caves will be 10 metres below the surface, with an ambient temperature of -50°C. Schedules have been stalled by the covid-19 pandemic, but the first cores could reach the ice sanctuary as early as 2023.

While storage is far from trivial, it is key to the Ice Memory project. On a typical mission, expedition teams aim to retrieve three ice cores, with only one for immediate analysis and ideally two saved for future generations of scientists. It is hoped that with knowledge and technology we don't yet have, more information can be extracted from these ice archives than we can dream of now. For example, Larose says biologists are just starting to understand how microorganisms communicate with each other, as well as the complex role that viruses play in nature, bringing useful survival genes to bacteria on the one hand, while decimating their populations on the other. "There's this constant evolutionary feedback and it would be cool to trace that over time," she says.

Even the immediate analysis of the cores is conducted with a long-term view: to create

reference data for future studies, which will be made available in a public database. As such, key centres for immediate analysis have attracted significant investment. For instance, the IGE has been transformed over the past two years with €1 million from Ice Memory, internal sources and private donors. At its heart is a "continuous-flow analysis" system, where ice core sections are transformed into water and gas, before measurements are taken.

The Ice Memory project's long view, centred on future generations of scientists, contrasts starkly with the short-term political wrangling that so often frustrates climate negotiations.

For Barbante, excitement over the new tools being developed to decipher the lessons from the past only heightens the urgency of preserving ice samples. "In a few decades from now, when these techniques will be available to unravel further insights of the climate, the ice of many high-altitude glaciers will no longer be available." There really is no time to lose. ■



James Dacey is a journalist based in Madrid, Spain



Mission scientists prepare to drill ice cores on the Mont Blanc massif, France, in 2016

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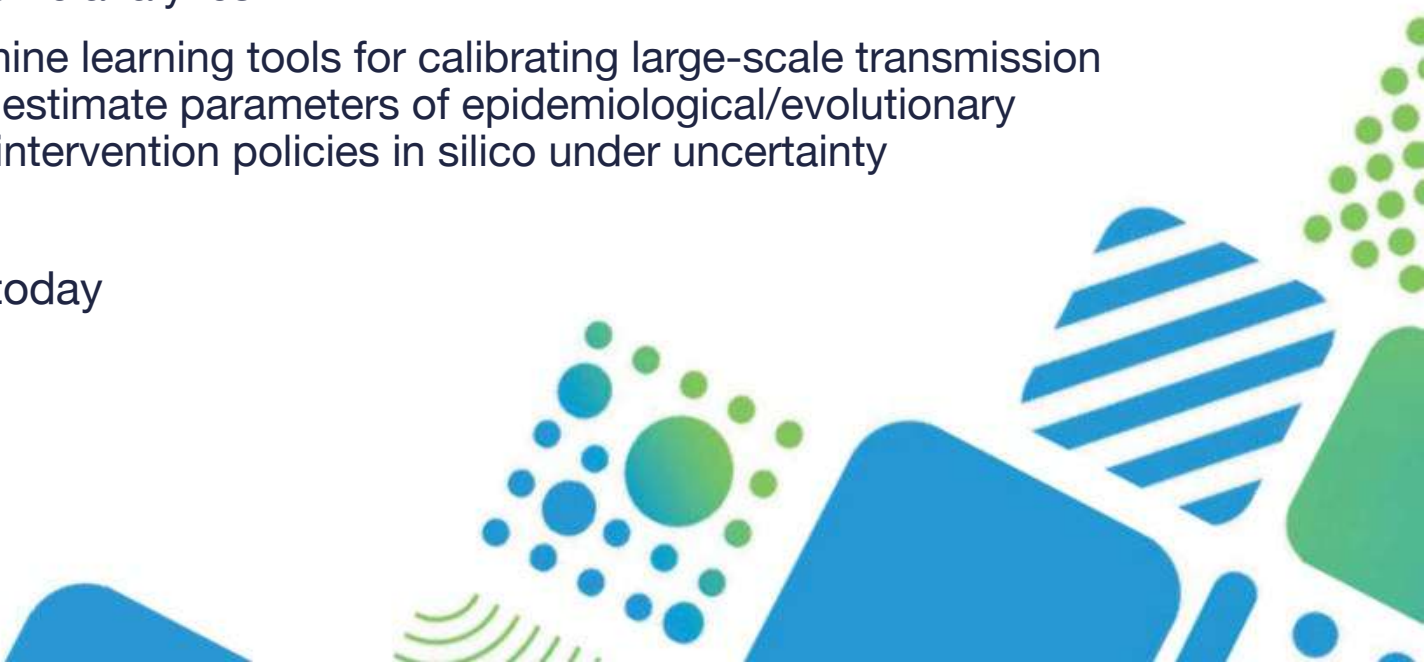
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Almost the last word

Would taller cyclists benefit from bigger-wheeled bikes? **p54**

Tom Gauld for New Scientist

A cartoonist's take on the world **p55**

Feedback

Scale uncertainty and a handy new way to cook a chicken **p56**

Twisteddoodles for New Scientist

Picturing the lighter side of life **p56**

Science of gardening

Love those bugs!

Aphids and other garden foes often make us reach for pesticides. Instead, a wildlife rethink could be in order, says **Clare Wilson**



Clare Wilson is a reporter at *New Scientist* and writes about everything life-science related. Her favourite place is her allotment @ClareWilsonMed

What you need

Lots of plants
No pesticides, especially not synthetic ones

AS MOST of the UK recovers from a frigid April and a soggy May, its gardens are starting to perk up. That means so are caterpillars, aphids such as greenflies, and other plant-feeding invertebrates generally seen as the gardener's foes.

A common reaction to seeing prized plants covered with bugs is to reach for the pesticide spray. But we should temper that instinct, says Andrew Salisbury, principal entomologist at the UK Royal Horticultural Society. Many invertebrate species in the UK and elsewhere are in decline, and gardens can be a haven – the UK's home gardens collectively add up to an area larger than the country's official nature reserves.

You might think there is no shortage of aphids, but they are food for bigger insects, such as ladybirds, lacewings and wasps, not to mention blue tits. While gardens are a much understudied ecological resource, some work suggests they can support hundreds of invertebrate species, including at least two insects in decline in the UK: two-spot ladybirds and, in the south, stag beetles.

Most synthetic pesticides kill aphids' insect predators too – and aphids tend to bounce back faster than their predators, requiring repeated spraying. If you must spray, try to use organic, soap-based products, which tend to be less harmful to predators – though they aren't completely non-toxic, says Salisbury. He doesn't advise home-made soap solutions as they haven't been tested for their



DUNCAN MCEWAN/NATUREPL.COM

effects on plants or wildlife.

There are other ways you can encourage invertebrates into your garden, according to a four-year study by Salisbury and his team. These include denser planting (although spiders love bare spots between plants) and choosing British species. The researchers compared how many invertebrates could be supported by three types of typical garden planting scheme: native British plants, "near-native" plants (defined as those from the same genus found in the northern hemisphere) and exotics, or those from the southern hemisphere.

Native plants were the best at supporting ground and foliage-dwelling invertebrates, but the difference wasn't that big. For example, 18 exotic plants supported the same number

of bugs as 17 near-native and 14 native plants of the same size.

The exception was for pollinating insects, such as honeybees, wild bees and hoverflies. These appreciated the exotic flower beds in late summer and autumn, when they had more blooms. As a result, the team recommends that UK gardeners focus on native plants with some exotics mixed in to extend the flowering season.

But Salisbury's main message is that, as far as possible, gardeners should relax about nibbled foliage, aim for a profusion of varied plant species and let the wildlife share their space. "It's not a garden, it's a living ecosystem," he says. ■

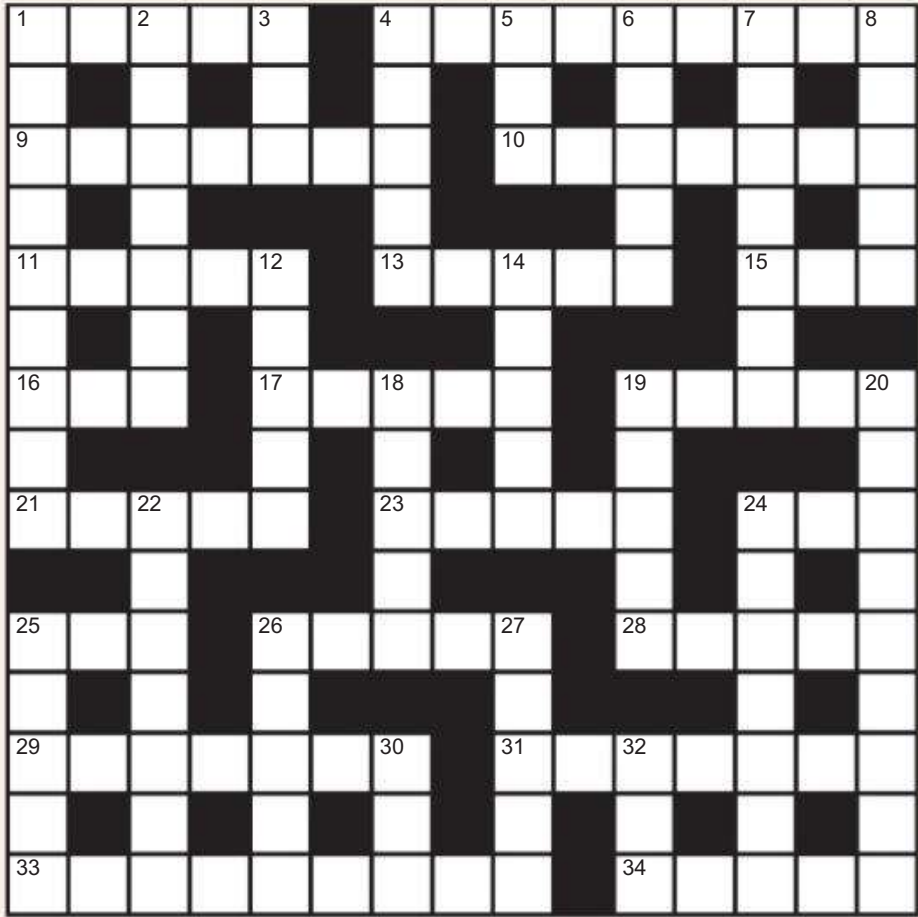
Science of gardening appears every four weeks

Next week

Science of cooking

These articles are posted each week at [newscientist.com/maker](https://www.newscientist.com/maker)

Quick crossword #85 *Set by Richard Smyth*



Scribble zone

Answers and
the next cryptic
crossword next week

ACROSS

- 1** Term for the position of bodily organs (5)
- 4** Inflammation of the kidneys (9)
- 9** ___ plague, infectious disease (7)
- 10** Si (7)
- 11** Type of communications firm (5)
- 13** Clock faces, for example (5)
- 15** Evergreen tree, *Taxus baccata* (3)
- 16** Breathable gas mixture (3)
- 17** Precise (5)
- 19** Dawn (5)
- 16** α (5)
- 23** ___ message, notification such as 404 (5)
- 24** Feline (3)
- 25** Insect of the family Formicidae (3)
- 26** Chart (5)
- 28** Infectious disease (5)
- 29** Livestock signifier (7)
- 31** Ψ (7)
- 33** A, B, AB or O (5,4)
- 34** Type of steel girder (1-4)

DOWN

- 1** Lower layers (9)
- 2** Cylindrical and hollow (7)
- 3** Our star (3)
- 4** Battery type (5)
- 5** Exudate from a site of infection (3)
- 6** Charles ____, aviation pioneer,
partner of Henry Royce (5)
- 7** Hypothetical faster-than-light particle (7)
- 8** Connective tissue (5)
- 12** Ω (5)
- 14** Genus of plants with star-shaped flowers (5)
- 18** Amazon virtual assistant (5)
- 19** Viscous, sugary fluid (5)
- 20** Crude oil (9)
- 22** Small marsupial, now endangered (7)
- 24** Cells or tissue developed
in controlled conditions (7)
- 25** Sour; harsh (5)
- 26** Thyroid, pituitary or thymus, perhaps (5)
- 27** Turning or folding mechanism (5)
- 30** Unlocking implement (3)
- 32** Φ (3)



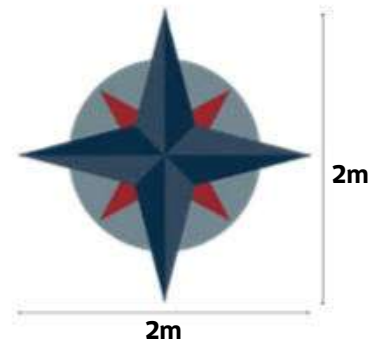
- 1 On which island would you find the smallest flightless bird species alive today?
- 2 How many toes does an ostrich foot have?
- 3 The first specimen of Darwin's rhea (*Rhea pennata*) was collected by which naturalist?
- 4 Which extinct creatures were the only known wingless birds?
- 5 What is the most numerous penguin species?

Answers on page 55

Puzzle

set by Zoe Mensch

#118 The spiky shield



Alice creates metal artwork, and her latest piece is a spiky shield, shown above. The shield is 2 metres across the spikes, and so Alice ordered a large box for shipping that was 2 metres square. However, the shield rotated in the box and could now rattle around freely, and Alice realised she needed a smaller square box into which the shield would fit as snugly as possible.

She went to order a new box from Box-U-Need, but discovered that its website annoyingly requires you to state dimensions in metres using whole number ratios. So if she wanted to order a box that was 1.5 metres wide, she would have to put in $3/2$ metres (or $15/10$ metres, if she felt so inclined). Worse still, the website only allows you to use numbers smaller than 20 on the top and bottom of the fraction, so a fraction such as $25/18$ would be rejected.

What is the smallest Box-U-Need box into which the artwork will fit?

Solution next week



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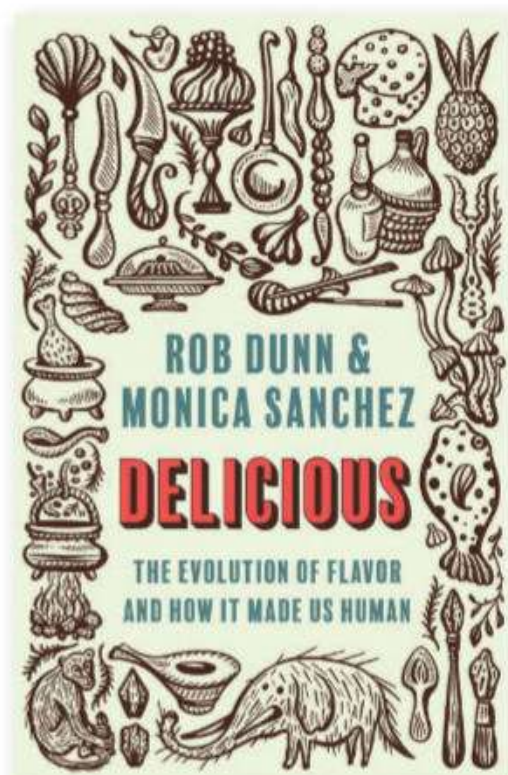
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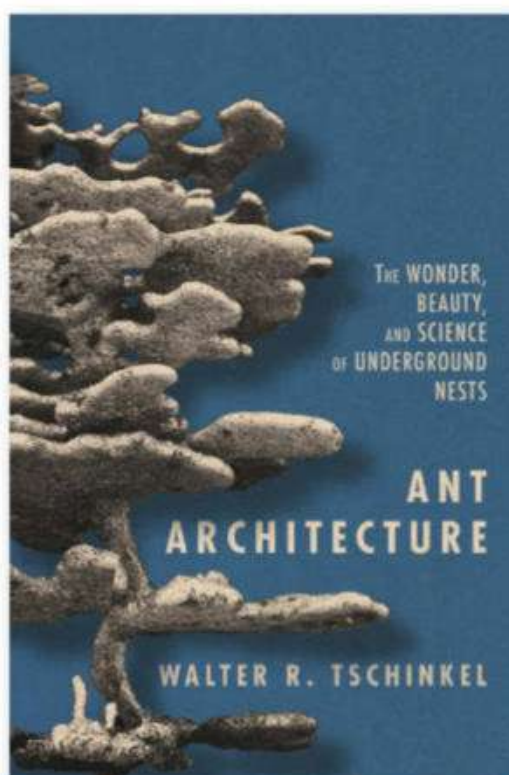
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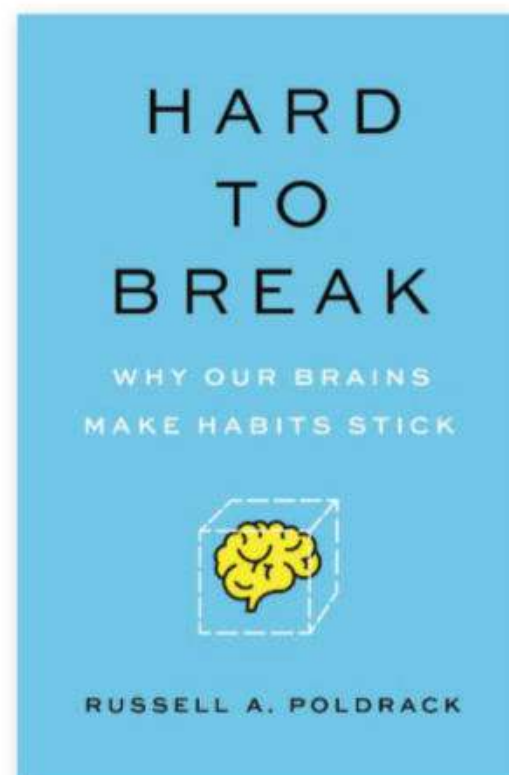
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—Angela Duckworth, author of *Grit: The Power of Passion and Perseverance*

Bike wheels

Bicycle frames come in different sizes to match the height of the cyclist, but the wheels stay the same size. Would there be any benefit in a taller rider having bigger wheels?

Stephen Johnson

Eugene, Oregon, US

Bicycle tyre size used to be a function of the height of the rider. This was true for the high-wheel bikes that became popular in the 1870s. Because these bikes required the rider's legs to reach the centre of the front wheel, the wheel radius had to be close to the rider's inseam length. For high-wheel bikes, the front wheel was also the bike's gear ratio and all had a relatively low gear.

With the addition of gear drives to bikes, their wheels became dramatically smaller and the resulting bikes were known as "safety bicycles".

Today, the wheel size of a bicycle is determined primarily by the frame geometry, intended purpose of the bike (road,

"Since smaller wheels are usually stiff, the ride on such bicycles can be harsh unless the frame geometry accounts for this"

mountain, racing or touring) and, to a much smaller extent, the size of the rider.

In addition, children's bikes, folding bikes and recumbent bikes often use much smaller wheels. Since smaller wheels are usually very stiff, the ride on such bicycles can be harsh unless the frame geometry accounts for this.

Chris Daniel

Colwyn Bay, Conwy, UK

Bicycles could be made with larger wheels for taller riders, but this is unnecessary thanks to the mechanical efficiency provided by the gears on modern bikes.

In the late 19th century, the high-wheel bicycle, or penny-

farthing, had a main wheel with a typical diameter of around 60 inches (152 centimetres). This design gave the greatest possible gear ratio from the pedal cranks, which were connected directly to the wheel hub.

A rider pedalling at a rate, or cadence, of 60 revolutions per minute would give the bike a respectable speed of nearly 17 kilometres per hour.

While the penny-farthing was comfortable, there were dangers of the rider sitting so high up, mainly due the risk of the bike tipping forwards when braking or going downhill. It was also very difficult to cycle uphill due to the poor mechanical advantage of the single gear.

Modern bicycles with smaller-

diameter wheels and a wide range of gears can go as fast as a penny-farthing for the same pedal cadence, while also allowing cyclists to travel faster in higher gears and to pedal uphill in lower gears with greater ease.

Rosemary Sharples

Penshurst,

New South Wales, Australia

Assuming that the bicycle is of a safety design with pneumatic tyres, rather than a throwback to the penny-farthing of the 19th century, there are several consequences of a cyclist having larger than normal wheels.

A bicycle with larger wheels than normal will also have a larger frame than normal.

The consequence of this is that,



GUY COX

This week's new questions

A low bow I saw a strange rainbow, at the wrong height compared with a normal one. It is supposedly impossible to see a rainbow at any other angle than around 42 degrees, but the arc of my "low bow" looked like 21 degrees (pictured). Can anyone explain? *Guy Cox, St Albans, New South Wales, Australia*

Turning point Do all planets rotate? If so, why? *Lyn Williams, Neath, West Glamorgan, UK*

Why would a rainbow appear at a different angle than normal?

between the wheels and other elements, the machine will weigh more than usual, all other things being equal. The rider will therefore need to exert more effort to propel the machine than they might otherwise, although the extra weight is likely to be insignificant.

What's more, the larger the wheel diameter, the further the bicycle will travel in one revolution. The rolling resistance of a bicycle is inversely proportional to the diameter of the wheel, so a larger wheel will present less rolling resistance than a smaller one. These aids to speed were the reasons why bike wheels grew larger throughout the 19th century.

On the other hand, a larger wheel will have a larger surface area and will therefore experience greater air resistance. But, again, the effect of this is likely to be negligible.

Since wheels are restricted to a few standard sizes, manufacturers have clearly decided that any difference provided by larger wheels isn't worth their trouble, even if the bicycle could cope.

David Cox

Adelaide, South Australia

Making a tall road rider even taller on bigger wheels would disadvantage them aerodynamically and could raise their centre of gravity, negatively affecting the handling of the bike.

In recent years, there has been recognition that mountain bike wheels with a 29-inch (74-centimetre) circumference offer advantages when riding over very rough ground, such as on rocks, compared with the original 26-inch (66-centimetre) wheels.

However, while 29-inch wheels offer rolling and gearing advantages, they have some disadvantages in acceleration and tight corners, suggesting there are limits to size's benefits.



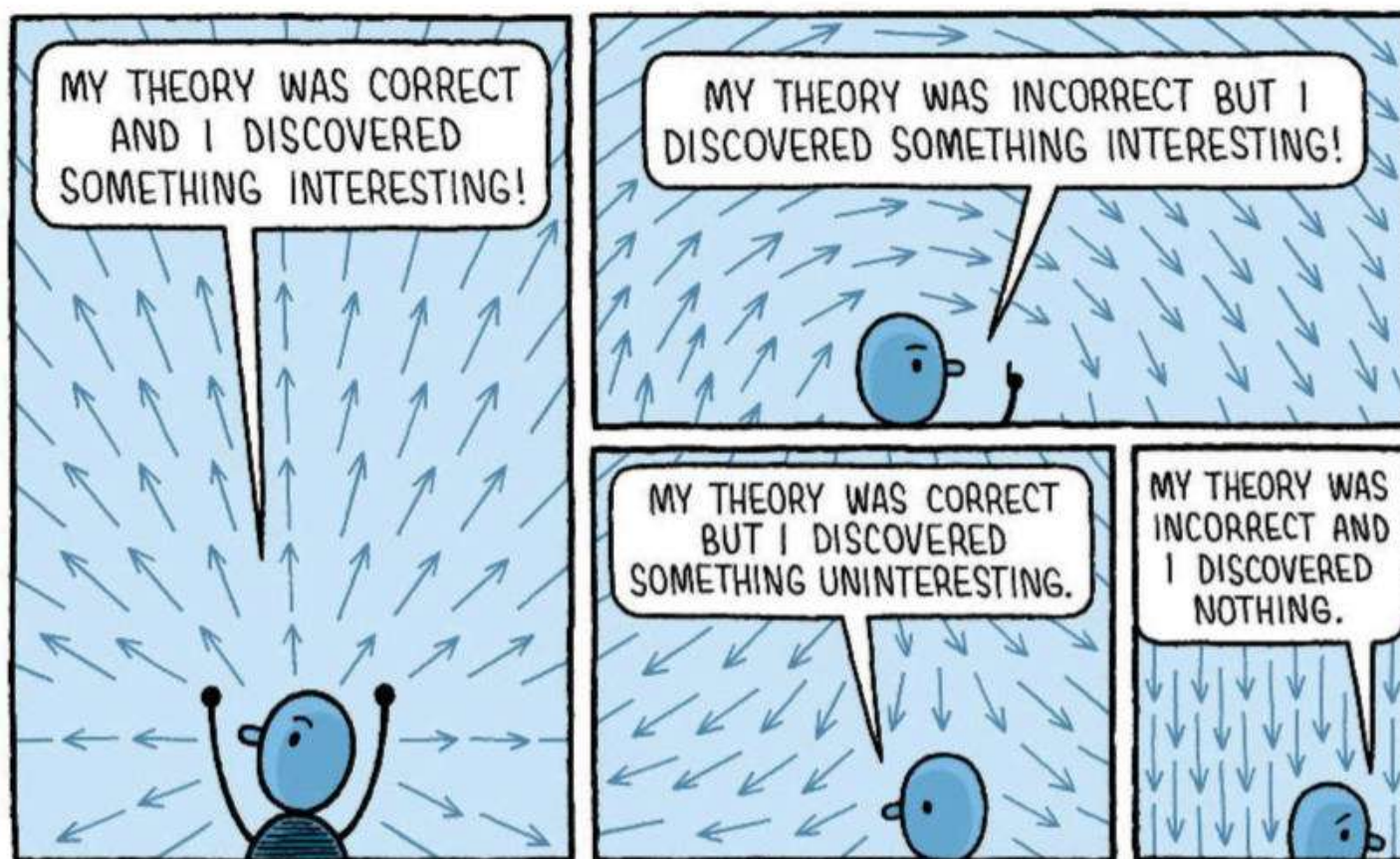
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Tom Gauld
for *New Scientist*



Loud sound

Is it possible for a sound to be loud but so brief that it can't be naturally heard by a person?

Simon Dales
Oxford, UK

Shock waves are very short in duration, and can be very loud. This is why we wear ear defenders for shooting. Rifles, and many pistols, fire at supersonic speeds. A rifle ball exits the muzzle at around 800 to 930 metres per second, but sound ambles along at 343 metres per second.

A rifle fired towards you sounds like "crack... thump". The crack is the shock wave of the bullet travelling past you. Eventually, the sound from the gun being fired arrives and you hear a thump. The bigger the range, the longer the gap.

If you want to use a silencer, it is best to use subsonic ammunition, which is designed to operate below the speed of sound. It is no good making the firing quiet if you have a noisy ball.

"Rifles fire at supersonic speeds. A rifle ball exits at around 800 to 930 m/s, while sound ambles along at just 343 m/s"

John Cooper
London, UK

In my youth club days, I owned a tape recorder and so was in demand for am-dram sound effects and the like. But repeated attempts to record the bursting of a paper bag failed. I wonder if the shock wave stretched the microphone's diaphragm to its limit, precluding the recording of the bang's decay. Could a loud bang's shock wave similarly "pin back" the eardrum?

Dropping off

How does our brain stop us from falling out of bed while asleep?
(continued)

Clive Tiney
York, UK

Presumably, when our ancestors

lived in trees, there was a distinct evolutionary advantage in not falling out of bed, a selection process that still goes on for arboreal apes and monkeys now.

Once we started sleeping on the ground, and now in beds, there was less reason not to fall out since the damage done isn't that great, but the instinct probably still remains even if it is diluting with time and passing generations.

Cots and bed guards for young children may also provide training for them to remain within the designated space, helping to restrict our sleep movements in the process.

Evan Bayton

Moore, Cheshire, UK

The one time I recall falling out of bed as an adult was when I was in a hospital in Blackpool. At about 8:10 am, I found myself on the floor.

I switched on the radio in time to hear the presenter say: "We are just getting word of an earthquake off the Fylde." ■

Answers

Quick quiz #106

Answers

- 1 Inaccessible Island, an overseas UK territory in the South Atlantic Ocean. The Inaccessible Island rail (*Laterallus rogersi*) is between 13 and 15.5 centimetres long
- 2 Two
- 3 Alcide d'Orbigny
- 4 Moas, which were hunted to extinction in New Zealand by the middle of the 15th century
- 5 The macaroni penguin (*Eudyptes chrysolophus*), of which there are an estimated 24 million

Cryptic crossword

#59 Answers

ACROSS 1 Rip off, 4 Thymus, 9 Granite, 10 Venus, 11 Snoop, 12 Eardrum, 13 Labradoodle, 18 Amalgam, 20 Ombre, 22/24 Dwarf planet, 23 Insular, 25 Impact

DOWN 1 Rugose, 2 Plato, 3 Flipper, 5 Hover, 6 Mandrel, 7 Sesame, 8 Legerdemain, 14 Atacama, 15 Opossum, 16 Hard up, 17 Regret, 19 Gaffe, 21 Balsa

#117 My fair ladybird Solution

You can win in four guesses (at most) if you guess B, C, C, B (or C, B, B, C). If the bean isn't there when you first guess B, it will be under either B, C, or D next round. If your second guess of C turns up empty, then it will either be under A or C next round. If your third guess of C still doesn't work out, the only place the bean can be on the fourth round is under cup B.

Ain't half hot

While slightly sweltering in a passable imitation of an English summer – missed it last year, was in the bath – on the whole, we would rather not be with Sydney Pulver in Philadelphia. He shares a screenshot of his local weather forecast declaring the temperature to be “94°F – like 152°”.

Feedback is sure the “like” is said with feeling, but with our purely scientific sun hat on, the nature of the equivalence is rather hard to parse.

“152”, we muse further, is a number hard to translate into a liveable temperature, whatever flavour of ° you favour. The closest we can get is with the Delisle temperature scale. This product of the 18th century, a particularly fun time for slightly off-the-wall temperature scales, takes the boiling point of water as its zero and works downwards from there in units two-thirds the size of those in the only slightly later Celsius scale. By that reckoning, 152°D would be about -1.3°C, or a shade under 272 kelvin for the absolutists among us.

None of which helps, but then neither does the Fahrenheit scale generally. We are reminded of the ongoing mystery of what exactly Daniel Gabriel Fahrenheit first used to define his scale. According to one well-worn story, 0°F was as cold as Fahrenheit’s home city of Gdańsk, Poland, got in winter, while 100°F was variously Fahrenheit’s own temperature, that of his dog’s rectum or that of melting butter.

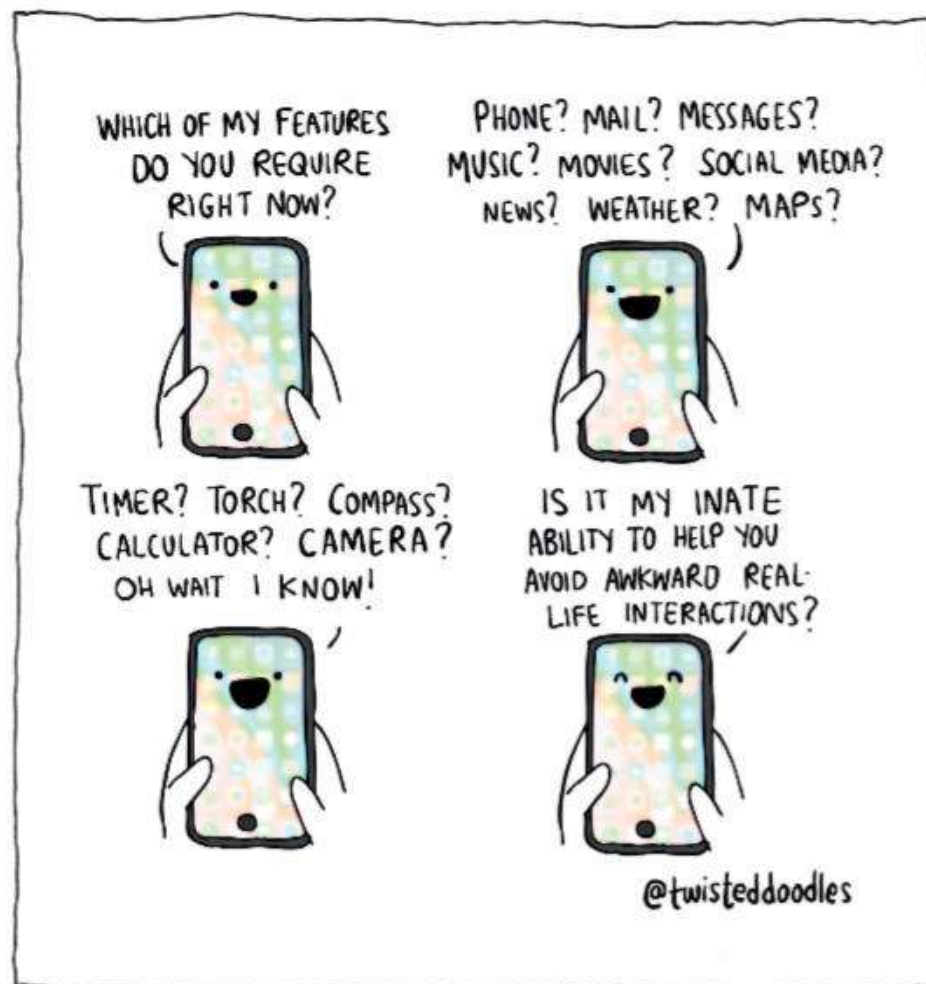
None of which helps either. It’s just hot, Sydney – like so hot.

Beating breast

Avoiding temperature altogether, as seems wise, can you cook a whole chicken by slapping it repeatedly? We have been trying on and off over the years – save energy bills, save the planet and all that – and failing. This is just one more factor in our continuing descent into vegetarianism.

Now YouTuber Louis Weisz has succeeded where we and many

Twisteddoodles for New Scientist



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Consideration of items sent in the post will be delayed

others have failed. Over the course of very many hours and 135,000 slaps, his “meat beater” mechanical slapping arm converted the requisite amount of kinetic energy to thermal energy fast enough for the chicken to retain heat and cook, but gently enough not to slap it into soup.

Big white hats off. With the wisdom of age, however, Feedback recalls that this isn’t the first such attempt to be crowned with success. As a cutting from the *Journal of Irreproducible Results* disgorged by our extensive piling system reveals, in 1987, researchers at the University of Southern Arizona slow-cooked a turkey by flinging it from the 10th floor of an administration building 72 times over the course of 6 hours. We can only presume it took about 5 minutes to get up the stairs again each time.

Stubborn growth

As a loyal subject, Feedback breaks cover to acknowledge the readers who wrote in to note that Her Majesty the Queen was recently presented with a new strain of rose in memory of the late Duke of Edinburgh by Royal Horticultural Society president Keith Weed. Weed has already featured twice in our pages (18 January and 15 August 2020), and we can only marvel at how he keeps popping up, however hard we try to keep him out.

Then there were five

National Geographic declares, excitingly, that Earth has not four oceans, but five. Our elation is only mildly blunted by learning that we haven’t found a new one down the back of the settee, nor is the publication referring to the

slightly cheaty one discovered locked up in Earth’s mantle.

No, this is the good old Antarctica-engirdling Southern Ocean. The National Geographic Society’s map policy committee has now decided, slightly later than much of the world, that its distinct circulation and other characteristics mean it merits its own moniker.

Feedback is caught between the rock of thinking there have always been seven seas and the hard place of looking at a map and seeing only one, much like there are only really three continents (and a bit, if we’re being nice to Australia).

But we admire *National Geographic*’s style, which is why we are now declaring, on behalf of *New Scientist*, the discovery of a fifth fundamental force of nature.

We aren’t particularly fussed which one – regular readers will know that physicists are hardly lacking in suggestions – but on the principle that it should be slightly underwhelming, we are plumping for a Higgs force. The means by which all fundamental particles acquire mass has been mired in procedural debates for years about whether it counts.

Enough. It’s a field, it’s a particle, it does stuff to stuff, and it’s pretty darned fundamental. We say so.

On the wax

“Nasa spacecraft captures first closeups of Jupiter’s largest moon in decades,” Sam Howison is startled to read in *The Guardian*, wondering how regularly it spawns new ones, or indeed how much they vary in size.

Questions beyond our wit to answer, Sam, although on the first one we have reason to believe that the moon in question, Ganymede, has been hanging around since at least 1610. For those who like their moons variable in size, we can only recommend a trick for next time Earth has a “supermoon” visible near the horizon: bend over forwards and view it upside-down through your legs. We promise you’ll be surprised. ■

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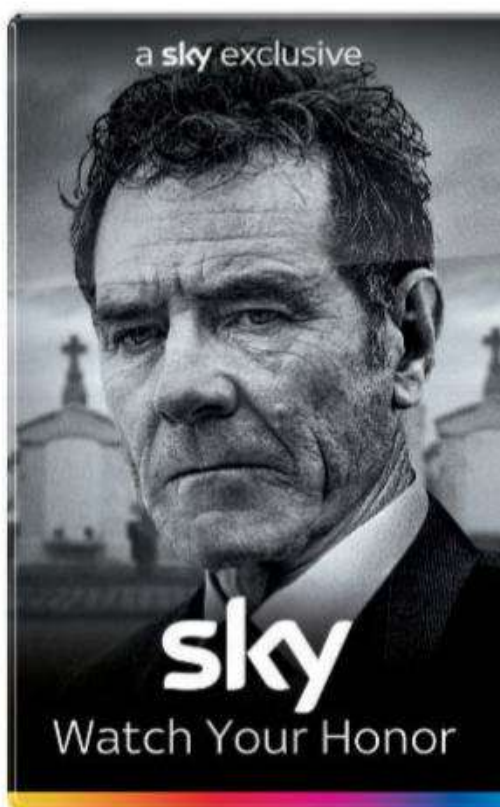
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